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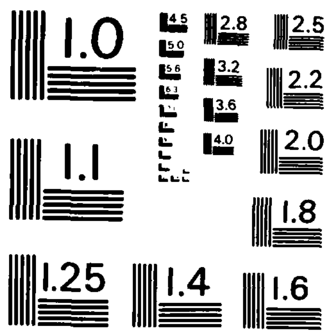

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AD-A161 367

ENERGY CONSERVATION IN THE HOME

BY

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A REPORT PRESENTED TO THE GRADUATE COMMITTEE
OF THE DEPARTMENT OF CIVIL ENGINEERING IN
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SUMMER 1985

For Delores, Scott and Heath

and in memory of my sister

FREDA MARILYN FOSTER

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CHAPTER ONE
ABSTRACT

Until a relatively short time ago, serious efforts to cut energy consumption and waste in U.S. homes were pursued by only a few builders and homeowners. Energy was inexpensive and resources seemed to be plentiful. However, when the sudden oil embargo in 1973 resulted in higher heating and cooling bills, the consumer became aware of the limited energy resources and the price of wastefulness.

People are now looking for ways of reducing energy consumption. Conservation may be voluntary for several reasons - perhaps because of patriotism, or because of unfavorable public pressures that come about when conservation efforts are not practiced, or because individuals feel that conservation is a part of their obligation to society. However, financial reasons for conservation become dominant when the price of energy increases to the point where it reduces the funds available for other desirable activities (1:8).

One way individuals practice conservation is by changing their life styles. Thermostats are lowered in homes during the winter months and higher temperatures are tolerated in the summer months. The consumer also looks for other potential energy savings in existing homes as well as when buying new homes. As the conscience of the people becomes tuned in to this new energy awareness, builders have little choice but to look for new

construction techniques that will provide homes that require less heating and cooling and therefore be more appealing to the money conscious consumer.

This report discusses some of the techniques used to conserve energy in the home. Chapter Two discusses insulation, how it works, why it is important, how it should be installed, and the various types that are used in homes today. Chapter Three provides an insight into the role that ventilation plays in conserving energy. Included in this chapter are discussions on the use of whole-house fans, ceiling fans, and attic ventilation systems. Chapter Four provides information about the types of doors and windows that contribute to energy waste and the types that contribute to energy conservation. Problems such as conduction, radiation, and air infiltration are also discussed. Chapter Five defines the different lighting systems available and compares these systems to one another as related to their energy usage. It also provides information on how to reduce energy consumption without inconveniencing the homeowner. Chapter Six discusses how computers can be used to determine cooling load requirements in the home. A dialoque type computer program is presented that can calculate how much energy can be saved through some of the various conservation techniques talked about in the report. This program is also capable of calculating the simple pay back period for those techniques considered. Chapter Seven of this report provides a summary and conclusion.

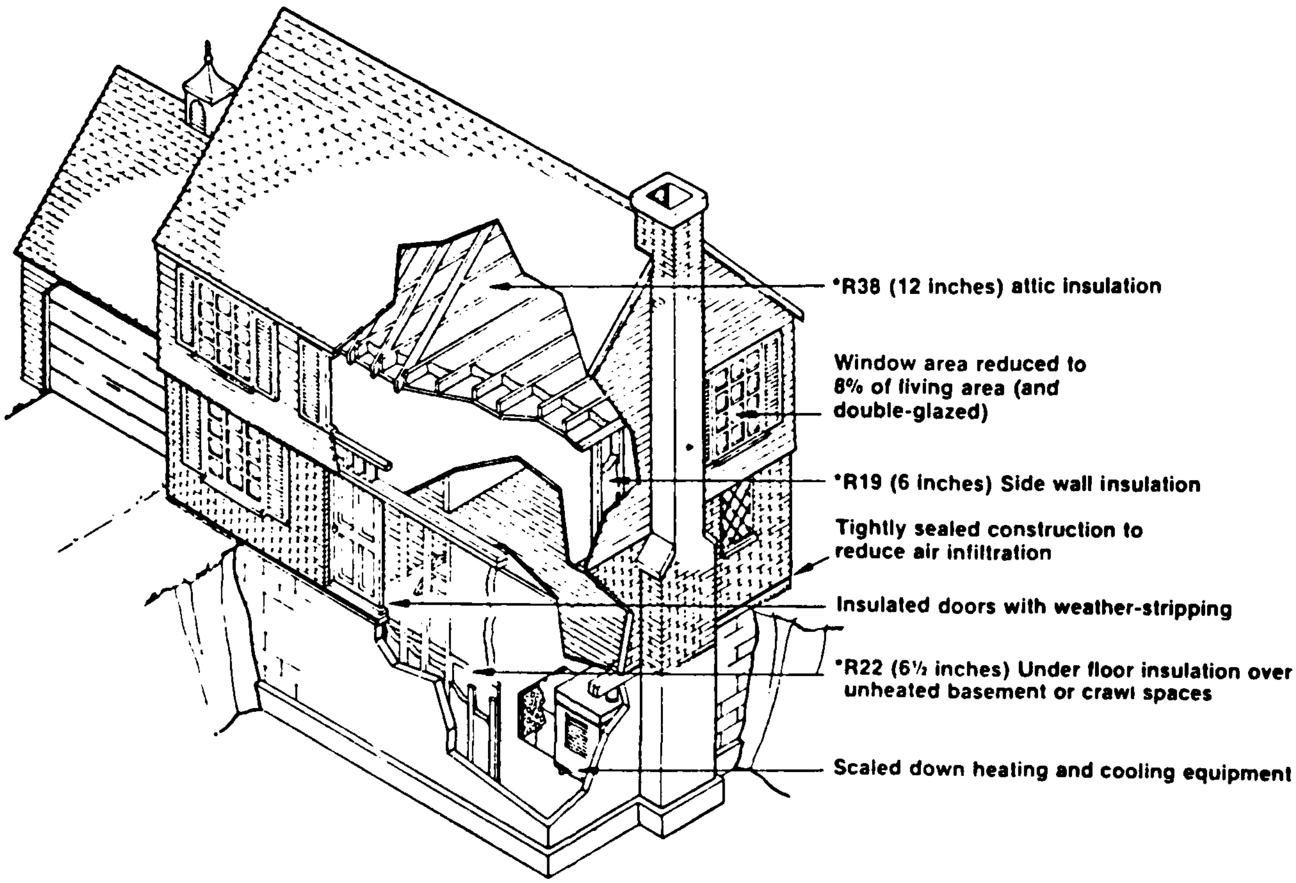


Figure 1.1 Some features of a low energy per month home (2:10).

CHAPTER TWO
INSULATION

2.1 Energy Savings

The addition of even a small amount of insulation in a home that presently has no insulation can dramatically reduce power and/or fuel bills. The addition of more insulation in homes that already have some insulation can also result in a substantial savings. Therefore, insulation is an important ingredient to energy savings in the home.

Many existing homes were built when energy costs were much cheaper than they are today. Consequently many homes do not have enough insulation and energy is being wasted. One study shows that the number of U.S. houses with adequate insulation is one in ten. Another estimates that almost two-thirds of U.S. homes should have more insulation while another one-third have no insulation at all. The National Bureau of Standards (NBS) reported that 40 percent of the energy (and dollars) consumed in home heating and cooling is wasted. Inadequate insulation is the major reason. Many homes, even today, lack sufficient insulation because energy conservation has never been a top priority for the government, the building industry, or the homeowner until recent years (2:09).

Major building codes did not require insulation before 1940. Until recently, the Minimum Property Standards (MPS) of the Federal Housing Administration (FHA) required only 1½ inches of insulation in the attic which is the most important area in the home to be insulated. Federal codes today require 6 inches of attic insulation. One estimate by the

NBS indicated that an investment in those 6 inches of insulation in an attic in a house located in a relatively mild climate where no attic insulation exists at present will result in a complete payback in one heating season as a result of the saved energy bills (2:09).

That payback is possible from only adding insulation in the attic. Even more savings can be realized from adding insulation to the walls and floor. The entire roof, wall, and floor areas that are exposed to the outside environment should be insulated for maximum dollar savings on heating and cooling bills. A typical estimate is that adequate insulation placed in an underinsulated home can save from ten to twenty percent in energy costs. Obviously, the actual savings depend on how much insulation was present to begin with, how much was added, the number of windows and doors in the home and the quality of weatherstripping (3:32).

Energy conservation can result in secondary benefits as well. Home buyers are checking energy bills as standard operating procedure before purchasing homes. If the energy bills are high in comparison to other homes in the area, the home may be very difficult to sell if it sells at all. Therefore, a home's resale value can be dependent on its energy usage.

2.2 Energy Tax Incentives

Not only does energy conservation result in lower bills, but also the federal government has now added an extra incentive. Owners may qualify for a Federal Tax Credit for part of their investment on certain energy-saving improvements. Fifteen percent of the investment made in insulation (as well as caulking, weatherstripping, storm windows, certain furnace improvements, and other items) may be claimed as a credit. The maximum credit for these items is $300. This credit is not a "tax deductible expense" that is taken off the short or long form - it is an amount that

can be directly subtracted from the total tax amount owed. Not all improvements and not all homes qualify. IRS Publication 903 can answer any questions about these credits (4:05).

2.3 How Insulation Works

Some heat is conducted by all materials. Those that conduct heat rapidly such as silver, copper and similar metals are classified as "heat conductors". Materials that conduct heat more slowly such as wood and other fibrous materials are classified as "heat insulators". Materials used in home insulation are of course heat insulators, but they have other characteristics as well: they are fireproof, verminproof and moisture-resistant.

Air is the very best insulator available. Trapped air is used in home insulation to achieve an effective heat barrier. In standard building insulation, air is trapped between millions of tiny fibers packed to a proper density which is an important factor. Material packed too loosely allows air to circulate and to be dissipated by convection (convection is the transfer of heat through fluids). On the other hand, material packed too tightly allows heat loss by conduction (conduction is the transfer of heat through solids).

Adequate insulation not only achieves greater energy and dollar savings, it also works in other ways to provide comfort for the inhabitants of a home. During the cold weather months, an uninsulated exterior wall can be between eight degrees and fifteen degrees cooler than a wall that is insulated. The cold can actually be felt with one's hand. All warm bodies will lose heat to cooler bodies through radiation. What this means is that the occupants sitting in a room with uninsulated exterior

walls will actually lose heat to those walls even though the room temperature is 70 degrees. This phenomenon is known as the "cold wall effect", and usually results in the occupants turning the thermostat higher in order to feel comfortable with the same thermostat setting of 70 degrees (2:10).

Of course the opposite occurs in the summer. Even though the air conditioner may be operating at full capacity, the occupants in a room with uninsulated walls will absorb heat from the walls and possibly turn the thermostat lower to feel comfortable.

Changing the thermostat up and down in order to acquire that comfortable feeling can greatly increase the fuel bills. If the thermostat is kept just three degrees lower in winter and three degrees higher in summer, a savings of at least five percent on an annual fuel bill is possible (2:11).

It can be seen that a function of insulation is to keep the entire room at about the same temperature. In an uninsulated room, heated air near a cold wall will cool off and move downwards to the floor while hot air will rise to take its place. This continuous circulation of air causes drafts; therefore, a room with well-insulated walls will have fewer drafts (2:11).

2.4 Placement of Insulation

As mentioned above, insulation should be placed in every area of the home which is exposed to the exterior. All insulated areas which will reduce heat loss in the winter will also prevent heat gain in the summer as well. If two adjacent rooms in a home are kept at about the same temperature, no insulation is needed between them. The only time insulation is needed between two interior walls is when one room is a conditioned space and the other is not.

Specific areas which require insulation are:

Exterior walls - all exterior walls and walls between living spaces and unheated garages or storage areas.

Ceilings - between conditioned and nonconditioned spaces.

Knee walls - only when the attic is finished as a living area.

Around perimeter of slab - if the house is slab-on grade.

Floors - again, between conditioned and nonconditioned spaces such as those over garages, crawl spaces or porches when the house is cantilevered. Unheated basements or crawl spaces can be significant sources of heat loss. Generally, any hot/cold interface should be insulated (5:07).

Basement walls - when this area is heated or used as living space. When a basement is unheated, the floor over the basement should be insulated.

Basement slab - when the basement is finished off as a recreation room. Not only will energy costs savings result, but also, the discomfort of a cold floor will be eliminated (6:10).

Attics - Not only is insulation in this area important in the winter, it is also important during the warmer months. In the summer, attic temperatures can be much higher than the outdoor temperatures on a hot day, and insulation prevents attic heat from pouring into the living space through the ceiling (7:22).

Several problems can occur while installing the insulation in the areas mentioned above. Some are the result of the type of insulation used, while others are the result of poor construction practices. A sample of common problems along with construction practices used to prevent or solve them are shown in Table 2.1 (8:02).

Table 2.1 Insulation prot 'ems and their solutions

Problem	Solution
Loose fill in a ceiling has peaks and valley	Screed to form a smooth, uniform layer height
Loose fill settles or rigid insulation shrinks over time in an attic	Refill to bring insulation up to desired level
Fill settles or rigid insulation shrinks over time in a wall	Blow new insulation into the void
Liquid foam traps air in top and bottom when blown into wall, preventing penetration of foam into all of the wall cavity	Run hose into bottom of area and carefully pull hose out as foam is blown in wall
Gaps between insulation batts (see Figure 1)	Butt edges of batting together in new construction, and patch or repair insulation in existing buildings
Compression of insulation to fit under or around construction items (cables, pipes, conduit, gas lines, electrical boxes)	Cut around and fit the insulation to the areas to eliminate air spaces

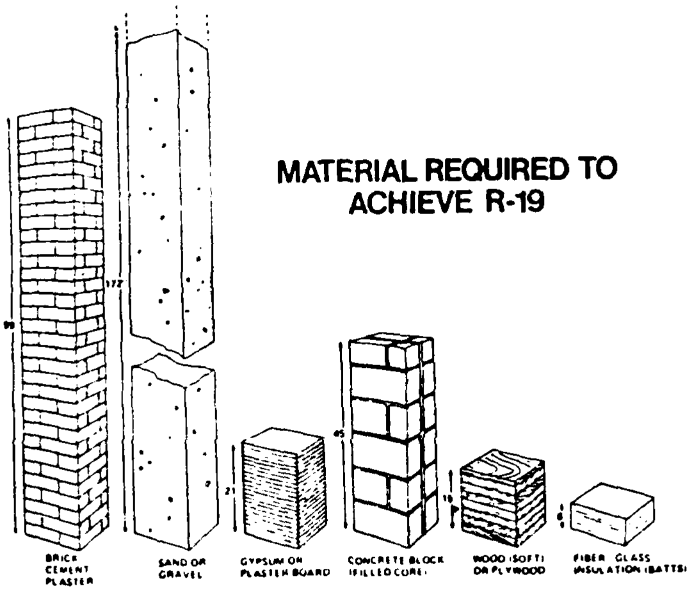
Source (8:02)

Thick insulation can be useless when it has been installed improperly. Every inch of exterior cavities must be filled with insulation material. Subcontractors may inadvertently remove insulation around wiring and plumbing. Even if only two or three percent of total wall and ceiling area is without insulation, the overall thermal performance of a home can be significantly downgraded (9:36).

2.5 "R" Value

All insulation is given an "R" value or "thermal resistance factor" value. This value is a measure of the ability of various ins lating materials to prevent heat flow through them. All insulation commercially available is marked with an "R" value on the label, for example, R-6, R-11, R-19 and so on. The "R" value is given for a certain thickness of material or the way in which it is used. The higher the number, the more effective the insulation (10:23).

The real value of insulation should never be underestimated. It is often heard that a basement with an 8-inch concrete block wall does not need insulation because the blocks are insulation enough. However, the fact is, it would take a wall four concrete blocks thick to provide the same weather barrier that just one inch of properly applied mineral wool insulation would provide. See Figure 2.1 (2:11).



Never underestimate the value of insulation. As shown above, a 6-inch layer of fiber glass insulation has the same insulation value (R-19) as more than 14 feet of sand or gravel (Certain-teed Products Corp.).

Figure 2.1 "R" Value of insulation (2:11).

2.6 Types of Insulation

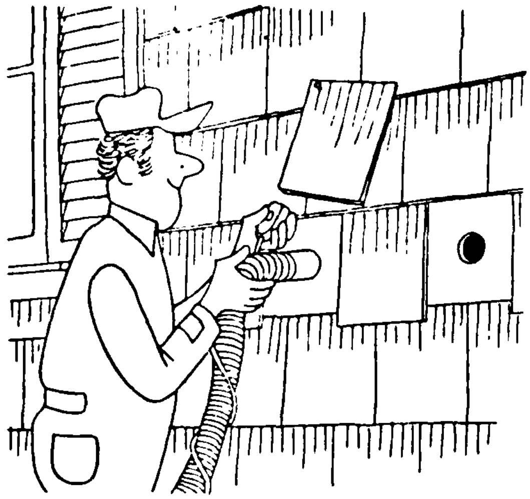
Insulation used in walls and ceilings can be either loose fill or rigid, block form. Loose fill insulation includes mineral fiber (fiberglass, rockwool), expanded mineral aggregates (vermiculite, perlite), and plastic foams (polystyrene, polyurethane, ureaformaldehyde). Rigid, block form insulation includes fiberglass or rockwool batts, bagged materials, foam blocks, and liquid foam blown into the walls of completed buildings (the foam subsequently dries into a rigid form) (8:01).

The most widely used type of insulation is mineral fiber. Mineral wool insulation is available in several different types, including blankets, blown insulation, poured insulation, and batts.

Blankets can be used in an unfinished attic floor, unfinished attic rafters, the undersides of floors, and in exterior walls. They come in rolls in a variety of lengths and are 15 inches to 23 inches wide. They come with or without vapor barriers. Blankets without the vapor barrier are called "unfaced insulation" (3:33).

Blown insulation can be used in unfinished attic floors and in finished frame walls. It is composed of loose pieces of insulation which are blown by air pressure into attics and walls. It is usually contractor-installed, and therefore is more expensive.

Figure 2.2 on the following page illustrates how a contractor blows insulation into an exterior frame wall of an existing home, increasing its "R" value.



In existing homes sidewalls can be insulated by a contractor who will blow in one of several loose fill materials (National Mineral Wool Insulation Assn. Inc.).

Figure 2.2 Blown insulation (2:21).

Poured insulation can be used on unfinished attic floors; it is especially suitable where joint spacing is irregular or where there are many obstructions. This can be an excellent choice for hard-to-get-to places.

Batts can be used in the floors of unfinished attics, unfinished attic rafters and the underside of floors. They are also available with or without vapor barriers. Batts are like blankets but are precut to 4-foot or 8-foot lengths. There is usually more waste in trimming batts to fit areas than with blankets (3:33).

2.7 Insulation Considerations

By now it should be clear that the proper insulation of a structure is a very important factor in energy conservation. Insulation is used to oppose the escape of heat. The quality of insulation is expressed by an

"R" value as discussed earlier. To determine the total thermal resistance of a home, the thermal resistance of the entire structure (wood, concrete, insulation, etc.) must be considered. The inverse of thermal resistance (1/R) is called the "coefficient of heat transfer" (U) and is an expression of the amount of heat flow through an area. This term is expressed in Btu per square foot per hour per degree Fahrenheit (Btu/ft^2/hr/°F). The following formulas can be used in the conversion of either R or U to electrical units expressed in watts (3:33):

$$\text{thermal resistance (R)} = \frac{1}{\text{coefficient of heat transfer}} = \frac{1}{U}$$

$$\text{watts (W)} = \frac{\text{coefficient of heat transfer}}{1} = \frac{U}{3.4}$$

or

$$\text{watts (W)} = 0.29 \times U$$

The manufacturers of insulation can provide data that shows the heat loss that can occur in homes of various types of construction. If a home does not have sufficient insulation to reduce heat loss, the heating and air-conditioning systems will be very ineffective. The heat loss of a home depends both on the basic building construction and the amount of insulation used. For instance, homes made of concrete have a different amount of heat loss than those made of a woodframe construction.

When the walls or ceilings are made up of layers of different materials, the "R" value is roughly the sum of the parts. For example, a wall with 6-inch fiberglass batts (R-19) plus 2 inches of extruded polystyrene foam sheathing (R-10) would have a total "R" value of R-29 (plus about R-3 from exterior siding and interior drywall) (9:36).

The following sample problem illustrates the importance of adding insulation to a house (3:33).

1. Given - A home consists of the following thermal resistance (R) factors:

   a. Exterior shingles are R = 0.90

   b. Plywood sheathing is R = 0.85

   c. Building paper used is R = 0.05

   d. Wall structure has an R = 0.90

   e. Wall plaster has an R = 0.40

   f. Insulation is R = 13.0

2. Problem - Find the total thermal resistance (R), the coefficient of heat transfer (U), and the watts (W) of heat loss both with and without the insulation.

3. Solution (without insulation):

$$R = a + b + c + d + e$$

$$= 0.90 + 0.85 + 0.05 + 0.90 + 0.40$$

$$= 3.10$$

$$U = \frac{1}{R}$$

$$= \frac{1}{3.10}$$

$$= 0.32 \text{ Btu/ft}^2\text{/hr/°F}$$

$$W = \frac{U}{3.4}$$

$$= \frac{0.32}{3.4}$$

$$= 0.094 \text{ watt heat loss}$$

4. Solution (with insulation):

$$R = a + b + c + d + e$$

$$= 0.90 + 0.85 + 0.05 + 0.90 + 0.40 + 13.0$$

$$= 16.1$$

$$U = \frac{1}{R}$$

$$= \frac{1}{16.1}$$

$$= 0.062 \text{ Btu/ft}^2\text{/hr/°F}$$

$$W = \frac{U}{3.4}$$

$$= \frac{0.062}{3.4}$$

$$= 0.01823 \text{ watt heat loss}$$

It can be seen from the results of this problem that adding insulation into the walls of a home has a great effect upon heat loss. The insulation has a much greater effect in controlling heat loss than do the construction materials. The proper installation of the proper amount and type of insulation can greatly reduce the energy consumption of heating and cooling systems in the home.

CHAPTER THREE
VENTILATION

3.1 Whole-house Fans

Ventilation to most people brings to mind the placement of windows and/or fans to achieve good air circulation and comfort. Mechanical ventilation cooling (MVC) (Figure 3.1), better known as "whole-house fan cooling" is used for this purpose. Many people believe that this fan is meant to cool them, but as its name implies, it is really best at cooling the house itself. During the day, the walls, floor, and furniture in a home absorb heat. Operating the whole-house fan when the temperature inside the house is higher than the outside will sweep the heat from those objects. In the summer, a whole-house fan can cut air conditioning costs by as much as 20 percent (11:6).

Windows should be opened to create an inlet area about twice the size of the fan area. The fan itself should be sized such that it produces about thirty air changes per hour. Multiplying the home's volume by 30 will result in the amount of air - in cubic feet - a whole-house fan should be able to move. Dividing this number by 60 will convert this measurement to a more common measurement of performance, cubic feet per minute (CFM) (7:24).

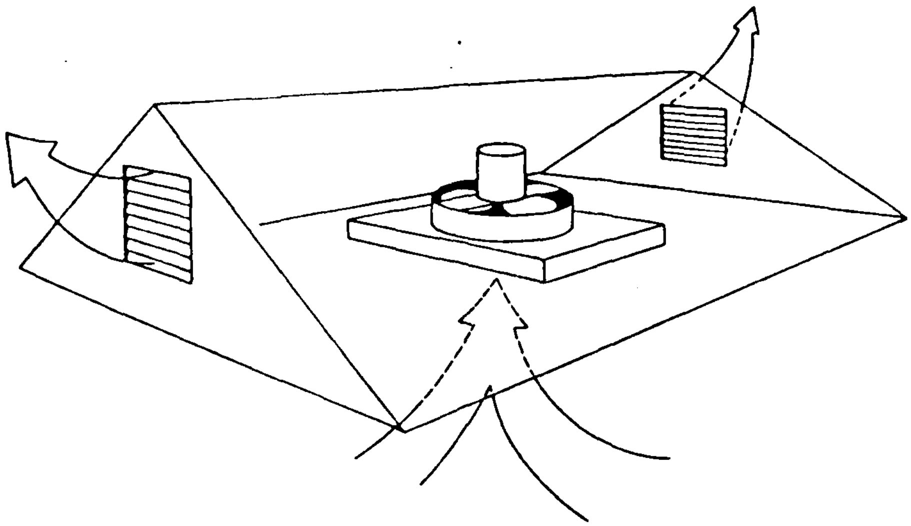


Figure 3.1 Typical mechanical ventilation cooling (MVC) fan (12:01).

3.2 Ceiling Fans

Another method of ventilation is provided through the use of ceiling fans. These low-speed fans are efficient. One that moves only 200 CFM can make torrid 87 degree Fahrenheit air feel like it is ten degrees cooler. Higher-speed fans are less efficient; they increase the velocity of the air movement but the comfort is not directly proportionate to this velocity. Air at 87 degrees moving at 1200 CPM - a sixfold increase over the 200 CPM - gives only seven more degrees of cooling than the 87 degree air moving at 200 CPM. Obviously that is not a significant increase in comfort for the increased energy usage. Also to be considered is the discomfort caused by the blast of air and the noise associated with higher-speed fans (7:24).

3.3 Attic Ventilation

Good ventilation also includes the movement of air in the attic. Attic ventilation has been around for quite some time. A look at 17th century farm houses may reveal no insulation, unless it was added later, but it will show plenty of attic ventilation. A correctly vented attic was then, and is now, very important because it reduces cooling costs in the summer and prevents moisture from damaging the insulation in the winter (13:84).

Most newer homes have adequate attic ventilation systems, and although older homes may have attic vents, they are often undersized. This undersizing was the result of old standards that are no longer appropriate because of the increased tightness of today's homes (13:84).

3.4 Summer Heat

During the hot weather season, the attic becomes unusually hot - hotter than any other part of the house. In a poorly ventilated attic, heat builds up during the day because it has no place to go. And although the temperature drops in the evening, the attic is unable to release any of the extremely hot air. It is simply trapped there, so heat continues to build up day after day; it can easily reach 150 degrees. If the home is not air conditioned, it is uncomfortable both day and night. If there is an air conditioner, it will be using a great deal of electric energy because it will have to work overtime. Figure 3.2 shows how proper ventilation can reduce the temperature in an attic.

The attic becomes heated due to the sun's radiation. Heat is transferred in three ways: (1) conduction, the transfer of heat through solids; (2) convection, the transfer of heat through fluids; and

(3) radiation, the transfer of heat by electro-magnetic waves. The house is subjected to large amounts of radiation even on a cloudy day. Anyone who has ever received a severe sunburn at the beach on a cloudy day can testify that the sun's rays are painfully potent (2:50).

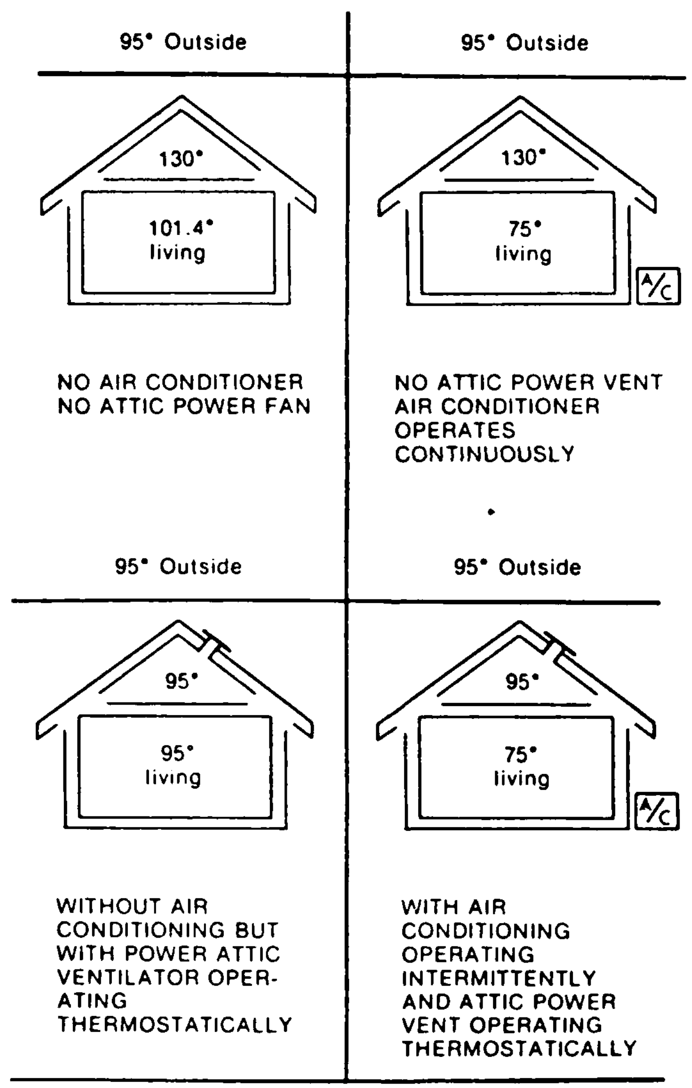
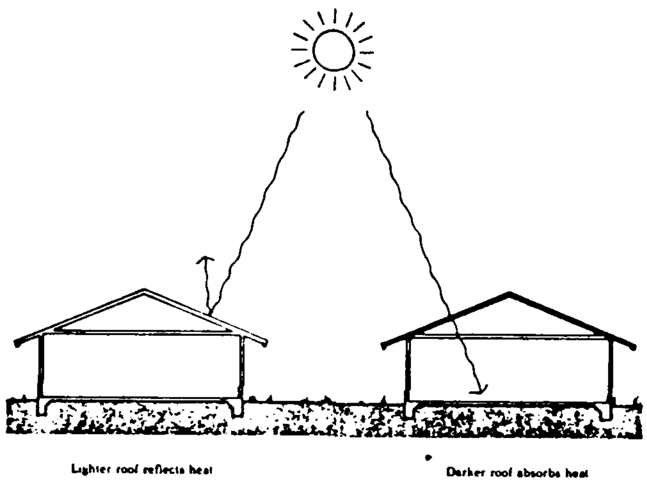


Figure 3.2 How proper ventilation reduces the temperature in an attic (2:51).

3.5 Heat Load Reduction

Shading can reduce the amount of radiation hitting the house. Light-colored shingles that reflect some of the sun's rays also reduce the amount of radiation. (Absorption of the sun's rays may be considered beneficial in areas that have long cold winters.) Nevertheless, even light-colored shingles will still absorb most of the sun's rays.



Select light-colored roof shingles to reflect sun and dark colors to absorb it (Owens-Corning Fiberglas).

Figure 3.3 Effect of sun on shingles (2:103).

The heat radiated by the sun is then conducted to the inside surface of the attic space from the shingles and roofing boards. Then the heat from the inside surfaces radiate to the attic floor causing it to become hot. The insulation (in an unfinished attic) or the attic floor now acts as a hot plate, heating up the air. And most important, at the same time the attic floor or insulation begins to heat up, it starts to penetrate

into the living space below. Insulation on the attic floor (as mentioned in Chapter Two) will retard the transfer of heat but it cannot prevent it.

Therefore, the real key to reducing this heat load is adequate ventilation. It not only rids the attic space of unwanted heat, but it also makes the insulation more efficient because the amount of heat with which it has to cope has been reduced. Proper ventilation may also allow the turning off of the air conditioner during the night and letting the attic ventilation and open windows cool the home. Even if the air conditioner is operating, a much shorter running and cooling time will be required (2:50).

3.6 Winter Moisture Build-up

Proper and sufficient ventilation is also important throughout the winter season. During this period, air circulation prevents efficiency-robbing moisture from becoming trapped in the insulation and on the walls and rafters. Once this moisture gets into the insulation, its effectiveness is dramatically reduced. Poor attic ventilation can, therefore, result in higher than normal heating bills in the winter because the warm air escapes through the wet attic insulation. Also such moisture can cause wood to rot, wallpaper to peel, and fine fabrics to become damp and moldy (10:22).

Two events can create water condensation in the attic area during the winter. They are: (1) in cold climates, the combination of high interior humidity - 40 percent or greater - and low outside temperatures cause frost to accumulate on the underside of the roof sheathing; (2) in moderate climates with high relative humidity, the day-night temperature cycle combines with high humidity to cause condensation on the underside of the roof (2:51).

This moisture condensation (in droplet or in frost form, depending on the climate) can be seen in the winter rather than in the summer because almost all of the inside ventilation is closed during this season. In the summer open windows, screened doors, etc. let in fresh air or take out much of the stale, moist air. Because the avoidance of drafts or air infiltration is important in conserving energy during the winter, less heat and water vapor from daily use such as cooking, bathing, heating, refrigerator operation, etc. escape from the home. With a tight home and plenty of water vapor, there is only one place for the moisture to go - up into the attic.

If water vapor, frost, or drops are present in the attic, ventilation problems are usually the cause. Continually damp structural members such as rafters and beams will deteriorate over time, and can result in major repair bills.

3.7 Ventilation Systems (Attic)

Two basic types of ventilating systems exist on the market today. One is natural ventilation using static ventilators that depend on the natural wind pressure and thermal effect. The other system is a motor-driven ventilator which forces hot air or cold, moist air out of the attic space through electrically powered ventilators. This system, obviously, does not depend on the weather conditions, but on electricity. There are a variety of motor-driven ventilators available on the market, including those that operate on low wattage. It pays in some cases to expend the extra energy to operate the power ventilators because they can actually save energy by making it possible for the air conditioning system to perform less work.

The primary purpose of attic ventilation is to change the air and to keep it moving. This ensures that moisture is removed in the winter and heat in the summer. However, for summer heat relief, more complete air changes per hour are necessary than in the winter because of the tremendous heat loads. It is generally recommended that about ten or more air changes take place in a one-hour period (13:84).

Whether the ventilating system is power or static, it must be sized properly and placed in the correct location to achieve air changes. The air flow is measured in cubic feet per minute (CFM) - a measure of performance discussed briefly at the beginning of this chapter. To achieve ten air changes an hour a minimum of 0.7 CFM per square foot of attic area is required. However, tests indicate that maximum attic temperatures can be reduced 44.5 percent with a ventilating rate of 1.5 CFM per square foot of attic floor area and 67 percent with 2.0 CFM per square foot. Air changes greater than 2.0 CFM per square foot do not reduce the temperature significantly (2:52).

3.7.1 Static Ventilators

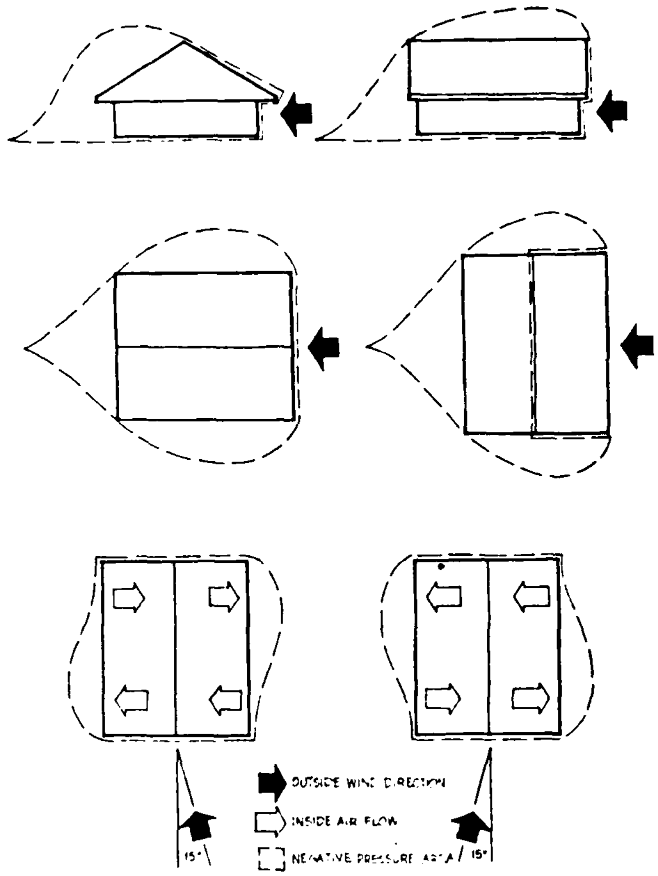
Air is replaced by static ventilators based on the square footage in the attic in proportion to the area of the clear vent openings. Attic vents are rated according to these clear vent openings or "net free area". This is the amount of vent area free of obstructions such as grille work, insect screens, louvered slats, turbine blades, etc. It is standard practice today to use one square foot of net free vent area for every 150 to 250 square feet of attic floor space (13:84).

In order to get the maximum air changes per hour, other factors must also be taken into account when considering static ventilators. One such factor is the placement of the vents which is just as crucial for the ultimate result in air change (13:84).

The wind pressure and the thermal effect of the homesite will determine the proper location of the vents. The vents should be able to fully utilize these two variables. Wind pressure is the more important of the two because when it blows and strikes the side of the roof, it tends to "jump", creating a vacuum or negative pressure on portions of the roof or side of the house. This vacuum or negative pressure causes the air to be pulled back toward the house, causing a positive pressure. For balance, equal quantities of vents should be located within both the positive and negative pressure areas. Vents placed in the negative area will allow the air to be pulled out of the attic, while vents placed in the positive area will pull air into the attic. See Figure 3.4.

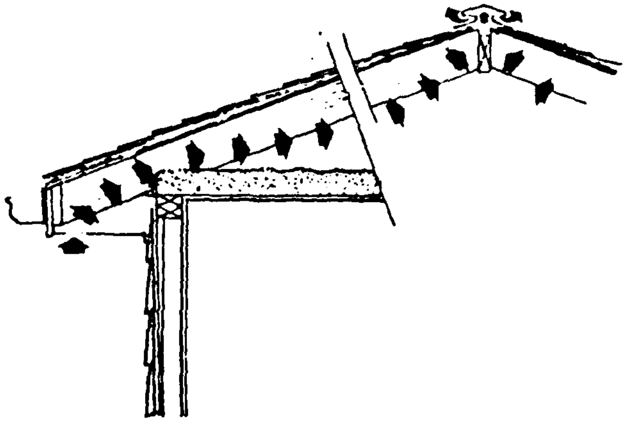
Placement of vents are also influenced by the thermal effect. Because hot air rises, high vents will let out the escaping overheated air while low vents will replace the hot air with the cooler outside air.

Obviously there is no guarantee that wind pressure and thermal effect will continually change the air; therefore, other considerations come into play. Because wind directions change, static ventilators are placed as "continuously" as possible. This will minimize the effect caused by the difference in wind directions by allowing the net free area to be effective regardless of wind direction. Placing the vents in locations where the weather cannot penetrate into the attic is also an important consideration.



When wind blows against a house, it causes negative and positive pressure areas. Vents in the negative area allow air out, in the positive area they allow air in (H C Products Co.).

Figure 3.4 Effects of wind pressure against a home (2:52).



As hot air rises out of the top vents, cooler air replaces it in the lower vents. Good ventilation always takes advantage of this thermal effect (H C Products Co.).

Figure 3.5 Thermal effect (2:53).

3.7.1.1 Roof Louvers

These small domes should be mounted near the ridge of the roof. They are available in aluminum, plastic, steel or wood. Aluminum ones are the least expensive. They can be purchased with screen or slit openings to prevent the penetration of insects. However, screens may cut down on the airflow and become clogged with dust, dirt or insects. Slit-type designs resist insect penetration and also avoid clogging problems.

3.7.1.2 Turbine Wheel

The turbine wheel is the variation on the roof louver. The difference is that the turbine wheel turns when there is sufficient wind and therefore draws air out of the attic space much more effectively. Unfortunately, like the roof louvers, severe weather conditions may penetrate through them and cause damage to the home.

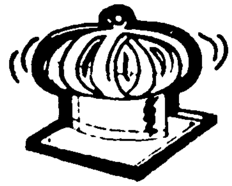


Figure 3.6 Turbine wheel (2:53).

3.7.1.3 Gable-end Louvers

Triangular vents for gable ends, (rectangular ones are also available), are designed for installation in the two gables as close to the roof as possible. When the wind is perpendicular to those louvers, the same vent acts as both an intake and exhaust. The air change, however, is small. When the wind is blowing parallel to the gable ends, one louver acts as an intake and the other as an exhaust. When this occurs, the rate of flow of air into the attic is equivalent to 70 percent of the wind velocity. As the air enters, it moves toward the floor and then up and out the other vent. The area of air flow, however, is limited in width by the size of the vent. These louvers also permit severe weather conditions to penetrate into the attic (13:84).

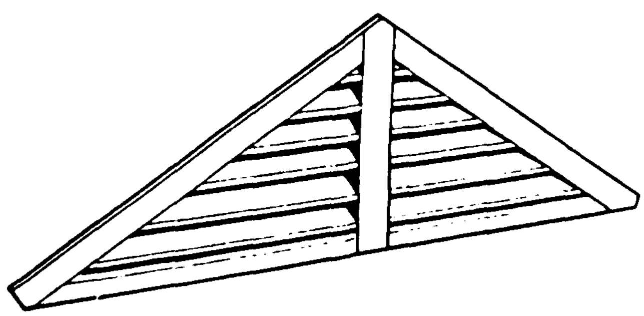


Figure 3.7 Gable-end louver (2:53).

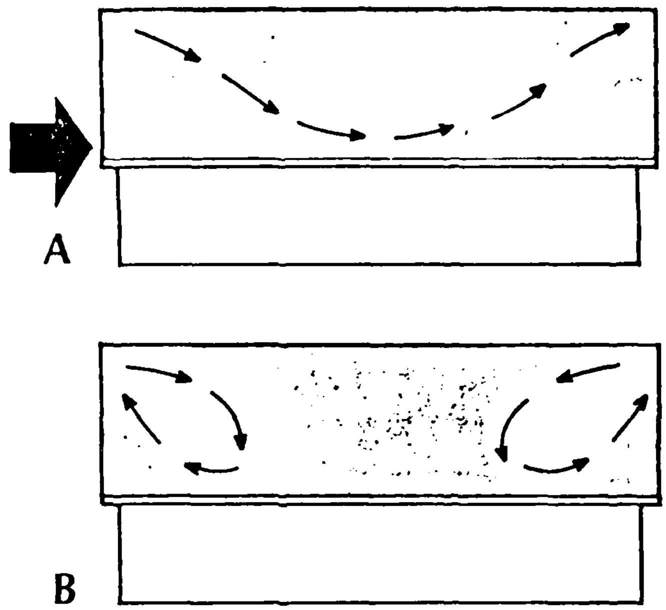


Figure 3.8 (A) The effect of parallel winds on gable-end louvers; (B) Perpendicular wind effect on same louvers (2:55).

3.7.1.4. Ridge Vents

This type of vent provides a continuous opening along the entire ridge line of the roof and is mainly available in aluminum. The net free area is normally 18 square inches per lineal foot. Primarily an exhaust vent, it provides uniform continuous air flow along the entire roof sheath surface (2:54).

3.7.1.5 Soffit Vents

This type of vent provides cool-air entry and offers the only air flow which is near the floor plus effective air circulation no matter what the wind direction may be. This is possible because the vents are positioned on the horizontal and therefore are always parallel to the wind. However, this type of vent will not

drastically reduce the floor temperature during the summer because of the radiation problem. Unfortunately this system will not cool the roof sheathing either.

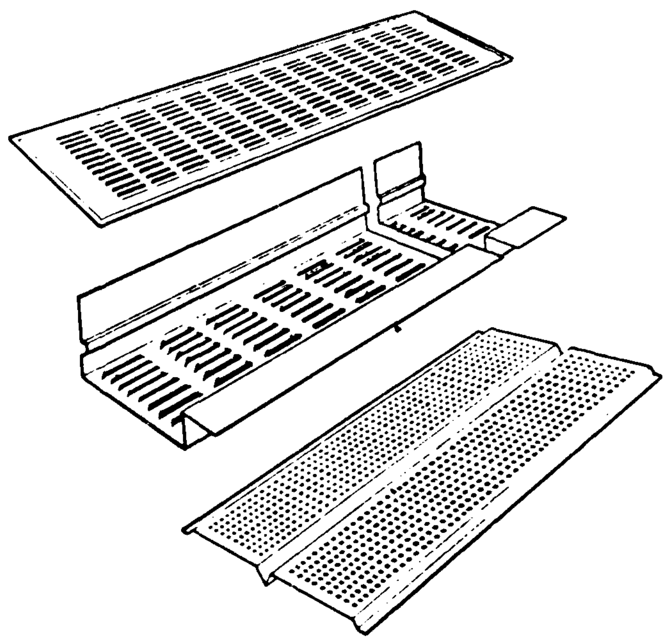
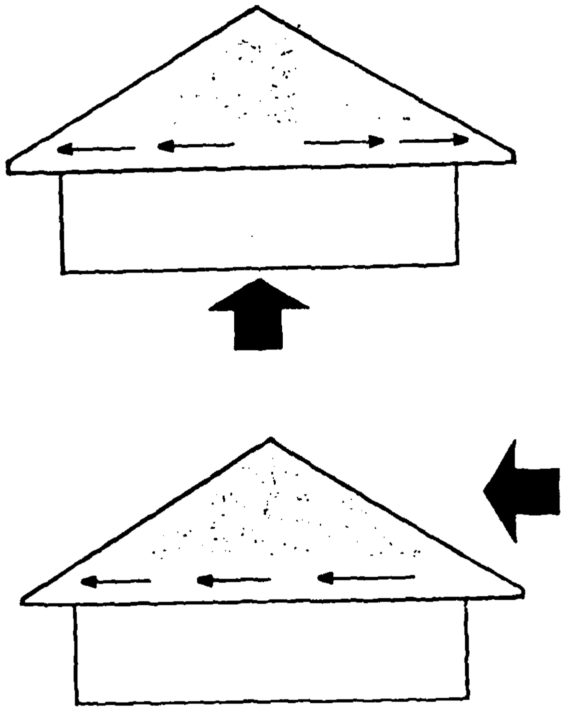


Figure 3.9 Soffit vents (2:54).



Soffit vents are effective regardless of wind direction but do little to lower attic floor temperature (H C Products Co.).

Figure 3.10 Effectiveness of soffit vents (2:54).

3.7.2 Vent Combinations

No one particular type of vent can solve all the natural ventilation problems which include wind pressure, thermal effect, radiation heat, wind direction and weather conditions.

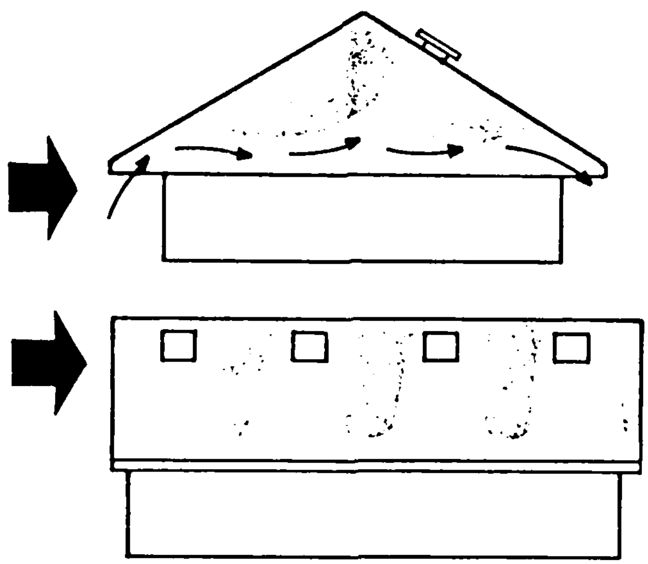
Even large numbers of roof louvers will not give proper ventilation if not used with other vents because the only area vented is the area between the various roof louvers. Also, unusual weather conditions can force moisture into the attic space causing problems that should be avoided if at all possible.

Gable-end louvers ventilate only small areas. They also achieve minimum efficiency with perpendicular winds. As with the roof louver, moisture can be forced into the attic when this type of venting is used.

Ridge vents are an effective exhaust because they are always in the negative pressure area. However, if this vent is installed alone, it would have to serve as both an inlet and exhaust vent and would confine air flow to the top of the attic near the ridge (2:55).

Soffit vents do not pose any problems resulting from wind direction and air movement but they do not deal effectively with radiation heat buildup.

Since ridge vents, gable-end louvers and roof louvers are placed high physically and are used in a similar manner, they each combine well with soffit vents, which have low and continuous placement in the attic (2:55).



It is difficult to balance the air flow with a roof louver and soffit vent system (H C Products Co.).

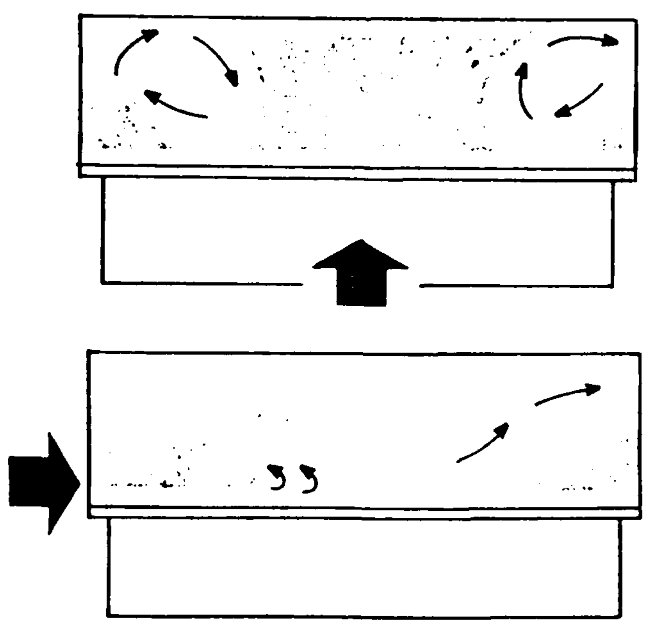
Figure 3.11 Unbalanced air flow (2:55).

3.7.2.1 Roof Louvers with Soffit Vents

A combination of roof louvers with soffit vents provides high and low vent areas. However, it is practically impossible to install enough high vent area for a balanced system. The combination provides about the same amount (not type) of ventilation per square inch of vent area as soffit vents provide alone. Air movement is confined to a few areas adjacent to roof and floor (2:55).

3.7.2.2 Gable-end Louvers with Soffit Vents

This combination also provides high and low vent areas. However, the air flow patterns created by this combination are the same as when each type of vent is used alone. Consequently most of the air movement is adjacent to the attic floor (2:55).

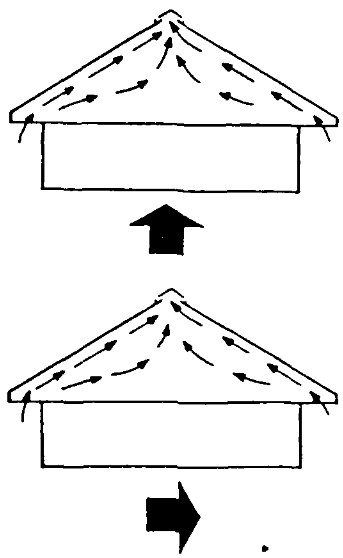


Gable-end louver and soffit-vent system does not alter air flow patterns of each unit (H C Products Co.).

Figure 3.12 Air flow patterns (2:55).

3.7.2.3. Ridge Vents and Soffit Vents

This combination utilizes the highest vent and the lowest vent and offers an efficient sytsem to make the most of the thermal effect, wind pressure and direction. The continuous soffit vent supplies the attic with enough air to assure a steady flow out through the ridge vent along the entire roof sheath surface (2:55).



Ridge and soffit vents provide the best combination (H C Products Co.).

Figure 3.13 Unbeatable combination (2:55).

3.7.3 Determining Amount of Venting

Table 3.1 can be used to estimate the amount of venting needed for an attic space (in inches of net free area). The ratio of 1 to 150 is considered good; the ratio of 1 to 300 is considered absolute minimum (2:56).

Table 3.1 Net free area (sq. in.) to ventilate attic.

Length (in feet)	Width (in feet)															
	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
20	192	211	230	250	269	288	307	326	346	365	384	403	422	441	461	480
22	211	232	253	275	296	317	338	359	380	401	422	444	465	485	506	528
24	230	253	276	300	323	346	369	392	415	438	461	484	507	530	553	576
26	250	275	300	324	349	374	399	424	449	474	499	524	549	574	599	624
28	269	296	323	349	376	403	430	457	484	511	538	564	591	618	645	662
30	288	317	346	374	403	432	461	490	518	547	578	605	634	662	691	720
32	307	338	369	399	430	461	492	522	553	584	614	645	675	706	737	768
34	326	359	392	424	457	490	522	555	588	620	653	685	717	750	782	815
36	346	380	415	449	484	518	553	588	622	657	691	726	760	795	829	864
38	365	401	438	474	511	547	584	620	657	693	730	766	803	839	876	912
40	384	422	461	499	538	576	614	653	691	730	768	806	845	883	922	960
42	403	444	484	524	564	605	645	685	726	766	806	847	887	927	968	1008
44	422	465	507	549	591	634	676	718	760	803	845	887	929	971	1013	1056
46	442	486	530	574	618	662	707	751	795	839	883	927	972	1016	1060	1104
48	461	507	553	599	645	691	737	783	829	876	922	968	1014	1060	1106	1152
50	480	528	576	624	672	720	768	816	864	912	960	1008	1056	1104	1152	1200
52	499	549	599	649	699	749	799	848	898	948	998	1048	1098	1148	1198	1248
54	518	570	622	674	726	778	830	881	933	985	1037	1089	1141	1192	1244	1296
56	538	591	645	699	753	807	860	914	967	1021	1075	1130	1184	1237	1291	1345
58	557	612	668	724	780	835	891	946	1002	1058	1113	1170	1226	1282	1337	1392
60	576	634	691	749	807	864	922	979	1037	1094	1152	1210	1267	1324	1382	1440
62	595	655	714	774	834	893	953	1012	1071	1131	1190	1250	1309	1369	1428	1488
64	614	676	737	799	861	922	983	1045	1106	1168	1229	1291	1352	1413	1475	1536
66	634	697	760	824	888	950	1014	1077	1140	1204	1268	1331	1394	1458	1522	1585
68	653	718	783	849	914	979	1045	1110	1175	1240	1306	1371	1436	1501	1567	1632
70	672	739	806	874	941	1008	1075	1142	1210	1276	1344	1411	1478	1545	1613	1680

FHA Chart Chart utilizes 1/300 ratio, double for 1/150 ratio, divide by five for 1/1500 ratio

Chart gives the amount of net free area (in square inches) required to ventilate attic space of home. To use chart, measure length and width of each rectangular section of your attic. Locate length dimensions on the vertical column and width dimensions on the horizontal column.

Source (2:56).

3.7.4 Power Ventilators

Motor-driven vents require energy in the form of electricity to operate but are more compact for a given capacity. This type of power ventilator can be an excellent choice to replace an undersized static system since it eliminates the need to enlarge existing holes or to cut additional ones (13:84).

A thermostat usually activates a power ventilator at a preselected temperature and shuts it off at another preselected temperature which represents that the temperature has been sufficiently reduced. Some power ventilators are controlled by a manual switch; however, most just simply plug into an electric socket. The vents are located on the rear slope of the roof, near the peek and centered. Air intakes are located at the eaves. This combination reaches all attic space sufficiently. Power gable vents are available if roofing vents are satisfactory.

The size of the power vent needed can be estimated based on achieving at least ten complete air changes per hour. Table 3.2 gives specifications based on attic area. Wattage of the power vents will, of course, vary. There are some on the market that operate on 75 watts (2:57). Only the lowest wattage ventilator that still delivers the highest efficiency CFM should be purchased. A number to look for on a power ventilator is the EER, which stands for energy-efficiency rating. As the name suggests, the EER is an indicator of efficiency: the higher the better (14:47).

Table 3.2 Power ventilator requirements.

LENGTH IN FEET	WIDTH IN FEET															
	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
20	280	308	336	364	392	420	448	476	504	532	560	588	616	644	672	700
22	308	339	370	400	431	462	493	524	554	585	616	647	678	708	739	770
24	336	370	403	437	470	504	538	571	605	638	672	706	739	773	806	840
26	364	400	437	473	510	546	582	619	655	692	728	764	801	837	874	910
28	392	431	470	510	549	588	627	666	706	745	784	823	862	902	941	980
30	420	462	504	546	588	630	672	714	756	798	840	882	924	966	1008	1050
32	448	493	538	582	627	672	717	761	806	851	896	941	986	1030	1075	1120
34	476	524	571	619	666	714	762	809	857	904	952	1000	1047	1095	1142	1190
36	504	554	604	655	706	756	806	857	907	958	1008	1058	1109	1159	1210	1260
38	532	585	638	692	745	798	851	904	958	1011	1064	1117	1170	1224	1277	1330
40	560	616	672	728	784	840	896	952	1008	1064	1120	1176	1232	1288	1344	1400
42	588	647	706	764	823	882	941	1000	1058	1117	1176	1234	1294	1352	1411	1470
44	616	678	739	801	862	924	986	1047	1109	1170	1232	1294	1355	1417	1478	1540
46	644	708	773	837	902	966	1030	1095	1159	1224	1288	1352	1417	1481	1546	1610
48	672	739	806	874	941	1008	1075	1142	1210	1277	1344	1411	1478	1546	1613	1680
50	700	770	840	910	980	1050	1120	1190	1260	1330	1400	1470	1540	1610	1680	1750
52	728	801	874	946	1019	1092	1165	1238	1310	1383	1456	1529	1602	1674	1747	1820
54	756	832	907	983	1058	1134	1210	1285	1361	1436	1512	1588	1663	1739	1814	1890
56	784	862	941	1019	1098	1176	1254	1333	1411	1490	1568	1646	1725	1803	1882	1960
58	812	893	974	1056	1137	1218	1299	1380	1462	1543	1624	1705	1786	1868	1949	2030
60	840	924	1008	1092	1176	1260	1344	1428	1512	1596	1680	1764	1848	1932	2016	2100
62	868	955	1042	1128	1215	1302	1389	1476	1562	1649	1736	1823	1910	1996	2083	2170
64	896	986	1075	1165	1254	1344	1434	1523	1613	1702	1792	1882	1971	2061	2150	2240
66	924	1016	1108	1201	1294	1386	1478	1571	1663	1756	1848	1940	2033	2125	2218	2310
68	952	1047	1142	1238	1333	1428	1523	1618	1714	1809	1904	1999	2094	2190	2285	2380
70	980	1078	1176	1274	1372	1470	1568	1666	1764	1862	1960	2058	2156	2254	2352	2450

HVI Chart

To determine what size power ventilator is needed to cool your attic efficiently, find the length of your attic on the vertical column and the width on the horizontal column. Where two columns intersect, you will find the required CFM rated ventilator (Courtesy of Home Ventilating Institute).

Source (2:57).

CHAPTER FOUR
WINDOWS AND DOORS

4.1 Energy Leaks

Sealing energy leaks is a major concern when attempting to conserve energy in the home. Although adding insulation (see Chapter Two) is the best way to start, another place to look is at the doors and windows.

Being able to see through to the outside when standing inside a home, means that there are places for energy to be wasted. These places may be unintentionally planned, such as hair-line cracks, or planned carefully and lovingly, such as windows and doors.

A well insulated wall will always offer more efficiency than a window or door, no matter how well insulated they may be. However, an unnecessary amount of energy may be wasted if the doors and windows are not "tight". Between 30 percent to 50 percent of the home's total energy loss may be flying out of the windows and doors (2:23).

4.2 Causes of Energy Losses

As discussed earlier, there is bound to be some energy loss through windows and doors; therefore, it becomes necessary to keep it at an absolute minimum. This energy is lost through the normal processes of (1) conduction, (2) radiation, and (3) air infiltration. Although these processes have been briefly discussed earlier in this report, they will now be discussed as they are related to windows and doors.

4.2.1 Conduction

Basically glass is a conductor of heat. When the home is warmer inside than out, the glass will conduct air from warmer to cooler and vice versa during the summer months when warm air is conducted through the windows to heat up the cooler air in the house.

4.2.2 Radiation

Sun radiation in the winter helps reduce heating bills but can increase them during the hot summer months. The sun's rays are radiated through the windows and this process causes heat buildup at a tremendous rate. Radiation heat builds up during the day, and after sundown the cooling system has to work double or tripletime to get rid of the heat.

4.2.3 Air Infiltration

If the edges around windows and doors are not properly sealed, air infiltration becomes a problem. A draft coming from them when they are closed is a good indication that this problem may be serious. After several years drafts from windows and doors can be expected since they can be caused simply through normal everyday use.

4.3 Windows

Most energy-minded people today think that a home with large windows consumes more energy dollars than a house with smaller windows; however, this is not necessarily true. A house with spacious windows that are well designed, well located, and used properly can actually help save on energy bills. On the other hand if these windows are poorly designed, poorly located and are not used properly, they can cause the monthly energy bills to be unnecessarily high.

Large windows, if they are located on the south of a home and have good exposure to the winter sun, can help heat the home using solar energy. This energy costs absolutely nothing. Windows on the north side help keep the home cool in the summer but can become energy thieves in freezing weather by stealing heating dollars. Windows on the east or west side of the house cannot contribute much towards solar heat in the winter because of the southern angle of the sun. However, in May, June and July the sun reaches its northernmost boundaries, and will stream in the windows that face east and west and cause considerable heat buildup during the time of the year it is most undesired.

Unfortunately it is unrealistic to have all of the windows facing the south in a home located in a cold climate, nor to the north in a home located in a warm one. However, there are many ways to compensate for disadvantageous exposures from windows which otherwise offer good natural light, good air circulation, and a good view.

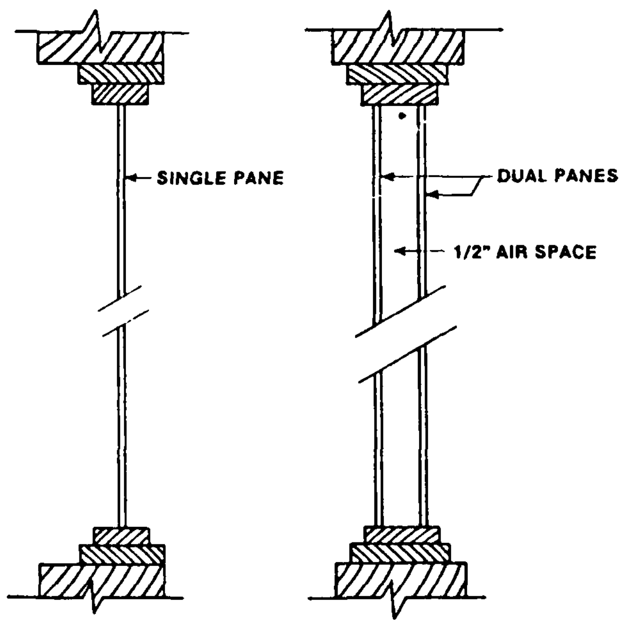
To ensure that the views provided by windows are not costing a bundle of money, the glass itself should be checked, not the exposure for the particular type of climate the home is located in. The installation of the window unit should also be looked at closely to determine if there are conduction, radiation or air infiltration problems.

4.3.1 Conduction Problems

In a typical wood-frame house, a wall that is insulated with 3 3/4 inches fiberglass batts will have a R-value of fifteen. A single pane of glass (called a single-glazed window) that is 1/8 inch thick, has an R-value of approximately one. A single-glazed window will easily permit heat to escape to the cold outside, or conduct heat from the outside into

the cool interior. Air, however, is an insulator - and luckily it is an insulation that can be seen through. To take advantage of this, there are double-glazed and triple-glazed windows (2:24).

Double-glazed windows are made up of double-insulated glass, usually with a ½ inch air space between the two panes. Glass with ¼ inch air space is also common - not as good, but not as expensive either. The ½ inch air space is more often found in commercial construction than in residential. The two panes of glass enclose a hermetically sealed space of dehydrated air. This acts as the insulation and has an R-value of about 1.5. Double-glazed windows are good; triple-glazed windows are even better. The three layers of glass enclose two separate air spaces and offer an R-value of about 2.9 (2:24).



Using double-glazed windows instead of single-glazed can mean an energy loss reduction of 50 percent (Owens-Corning Fiberglas).

Figure 4.1 Types of windows (2:25).

When it is zero degrees (Fahrenheit) outside and 70 degrees inside a home, a single-glazed window will have a temperature on the inside surface of 18 degrees! This is 14 degrees below freezing right inside the home. The double-glazed window maintains a temperature of 36 degrees on the inside surface, while triple-glazed windows enable a surface temperature of 51 degrees (2:24).

Adding an extra layer of glass to single-glazed windows will keep the temperature near the floor 3 degrees warmer. In terms of energy consumption, going from single-glaze to double-glaze means an energy loss reduction of 50 percent, from single-glaze to triple-glaze means a reduction of 65 percent. Going from double to triple will reduce the loss by only 15 percent (2:25).

Obviously a solution to the conduction problem is to add air insulation through double-glazed or triple-glazed windows. Hermetically sealed air spaces in "thermopane" windows is one way to provide the insulation; another way is adding an extra layer of glass with storm windows. After doing this, buying or making thermal-lined drapes should be considered. They can be effective against conduction and radiation because they act as both an insulator and light blocker. They also have an advantage in that they can be closed at night during the winter and opened to receive the full amount of solar energy during the day. Keeping them drawn in the summer daylight hours could also save on the cooling bill.

4.3.2 Radiation Problems

Insulation through extra glazing or thermal drapes can help radiation problems, too. Because a person's body is warmer than the window, it

radiates heat to that cold surface. Therefore, a person will feel colder and more uncomfortable in a room with single-glazed windows and no thermal drapes than in a room with protected windows.

In warm climates where radiation can be a terrible problem, reflective double-glass windows are now available. They help keep out about 75 percent of the sun's radiation. Blinds, shades, curtains and shutters as well as thermal drapes can block out both the summer radiation problems and the simpler heat conduction problem (2:25).

4.3.3 Air Infiltration

Air infiltration can be described as the unregulated entry of air into the living space of a home. This is quite different from ventilation which is the necessary, controlled entry of air. Air infiltration can be a serious problem in most homes because of natural wear and tear or faulty installation, or both. In any event it can cause a certain amount of heated air in the summer or frigid air in the winter to seep through the window units.

As previously stated if a draft can be felt near a window during cold or windy weather, an infiltration problem exists. In extreme cases the window frames may rattle, and often the glass within the frames will rattle also. A typical 36-inch by 52-inch double hung window which, due to wear and tear, has a slight 1/16-inch space around the sashes (the part that holds the panes) can create a huge energy leak. Adding up that 1/16 of an inch gap all the way around the perimeter of the window, will result in an equivalent hole that measures 13½ square inches, and that is only one window with normal wear and tear. The rest of the windows in a home could very well be in the same condition. The result can

probably be equated to leaving one or more windows open all winter long and then trying to heat the home (2:26).

Installing windows and storms that fit tightly is imperative - especially the storm windows. To ensure this, weather stripping and caulking are used. For windows which are permanently sealed with thermopane, caulking is used both inside and out. But on double-hung windows with storms, weather stripping is used for the movable sections and caulking is used for permanent areas.

4.3.4 Window Film

As stated earlier, glass lets light and heat in and out quite easily. Adding extra panes of glass certainly helps in controlling energy loss, but there is another way - thin plastic window films that can be applied to the windows presently in a home.

Unlike add-on storm windows, these window films are plastic sheets that have been modified with dyes or extremely thin layers of metal to enable them to filter different types of energy which include solar heat, visible light, and room-temperature radiant heat. These window films can selectively reflect or even block different types of energy depending on the mixture and thickness of the coatings.

For example, some films can allow large amounts of daylight to enter while blocking the solar heat that is unwanted in the summer months. Other films let in daylight and solar heat but prevent some of the room heat from radiating back outside - a situation unwanted during the winter months. This selectivity allows a resident to "fine-tune" the windows to provide the most desirable combination of light, heat, or shade. Another feature of window films is that do-it-yourself costs are relatively low - from \$.50 to \$3.00 a square foot (15:58).

4.4 Doors

Doors are usually more energy-efficient than windows but they can still be a source of wasted energy. Similar to windows, doors also suffer from problems such as air infiltration and conduction with air infiltration being the major problem. Doors are meant to be opened and sometimes they are left opened unintentionally causing a tremendous energy loss. It is important to keep the doors shut while the heating or cooling system is operating.

4.4.1 Air Infiltration

Doors on the typical single-family home are usually solid-core wood (doors mentioned in this chapter are all doors which lead outside). The average door which is about 1 3/4 inches thick has an R-value of about 2 (whereas a well-insulated wall has an R-value of 15). Hollow core doors used on the exterior should be replaced immediately! Not many homes have exterior hollow core doors these days, but it pays to check anyway (2:32).

Like windows, the only way to increase the R-value of a door is to add another layer with air in between. The typical solution is a storm door. A substantial wooden storm door will increase the R-value about 3.5 to 4, depending on the amount of glass, possibly used to show the features of the primary door. Aluminum storm doors will increase the R-value to about 3. Insulated steel doors with built-in thermal breaks rate as high as R-15 (16:30).

Some doors which are made of several pieces of wood often have air leaks within the unit while others leak around the door frame. Besides adding a storm door, the units must also be "tight" to be effective.

Weather stripping must be added around the door for best results. As in windows, the air infiltration problem may also require caulking (unlike the movable sections which take weather stripping around the door frame). About 80 percent of the total heat loss due to an exterior door is the result of the infiltration around the edges of the door (16:30).

Often overlooked is the gap at the bottom of an outside door. This gap can often be one of the greatest sources of energy loss in the home. Of course it can cause other problems as well such as water penetration during a storm which can damage the carpets, the floors and the sub-flooring.

A good seal will obviously prevent these problems. Probably the simplest and quickest way to provide this seal is by using a metal strip with a resilient vinyl bottom edge (see Figure 4.2). The type that is mounted with screws rather than nails is most often recommended because it allows adjustment of the strip as wear occurs.

Another type of seal which is more efficient and less visible consists of a matched set of interlocking channels - one on the door bottom, and one as an integral part of the threshold. Although this offers a much better seal than the metal strip, both types help prevent energy loss and are certainly better than having a gap at the bottom of the door (17:36).

4.5 Doors As Windows

Many builders and architects have increased the use of sliding glass doors using them as windows. However, in terms of conserving energy in the home, this is not a wise decision.

In areas specifically designed for windows, a window should be used, and if ventilation is not a requirement, a fixed glass window may be the best solution for getting natural light and/or a good view in the room.

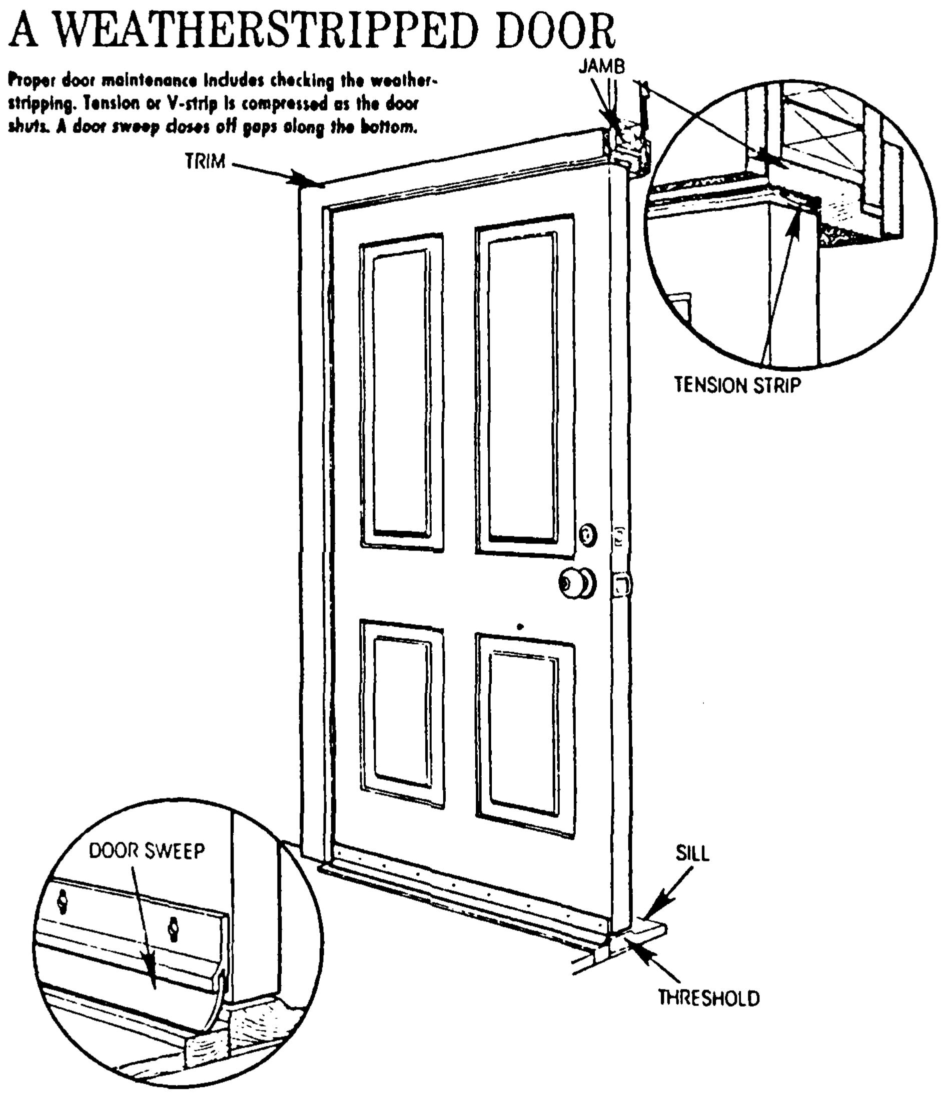


Figure 4.2 Door maintenance (16:108).

However, there are times when sliding glass doors can be beneficial. That is when space is at a premium and both light and the view are also overriding factors. But in all cases when contemplating sliding glass doors, thermopane ones should be considered. Thermopane doors cost more initially, but in the long run - not too long at that - the heating or cooling bills will more than make up for the difference (2:32).

CHAPTER FIVE
LIGHTING

5.1 Electrical Energy

When it comes to energy wastes in the home, lighting is probably one of the simplest to spot. It is one of the major uses of electrical energy and contributes significantly to the home cooling load as well. Reducing electrical usage for lighting results in both direct and indirect savings. A direct savings occurs through reduced electrical energy required for lighting, while indirect savings are incurred as a result of lower cooling loads which decrease the expenditure of energy to operate air conditioning systems. The visual energy output at many houses can probably be reduced quite easily without causing any discomfort. With a bit of planning, both the aesthetic and practical needs of the inhabitants can be improved.

Lighting systems are designed to convert electrical energy into light energy while creating a comfortable and safe environment. Several types of lighting systems are in use today, including incandescent, fluorescent, mercury-vapor, and metal-halide, all to be described later in this chapter. Lighting systems are a type of electrical load which represents a substantial amount of energy used in a home. The planning involved to obtain proper lighting design in a home can sometimes be quite complex and may involve several types of light. Therefore, it is important that anyone interested in energy management be familiar with the various types of lighting systems and their comparative energy use.

5.2 Important Terms

Several basic terms dealing with lighting should be understood before discussing lighting systems. The terms that follow summarize many of the items which are important in lighting design (3:92).

Ballast: A coil of wire (inductor) used to develop a high-voltage discharge for starting fluorescent and high-intensity-discharge (HID) lamps.

Coefficient of utilization: The ratio of the lumens of light on a work area to the total lumens of light produced by the lighting systems.

Color rendition: The effect of a light source on the color appearance of objects with reference to their appearance while subjected to a reference light source.

Contrast: The difference in brightness between an object and its background.

Diffuser: An object which is placed in front of a light source to control the amount of light emitted.

Efficacy: The ratio of usable light produced to the total energy input to a system or fixture. It is expressed in lumens per watt produced by a lamp.

Efficiency: The ratio of the illumination of an area to the electrical energy used to light the area.

Floodlighting: A lighting system designed to light a large area. Ordinarily, luminaires that can be aimed in any direction are used for floodlighting.

Footcandle: The amount of illumination a distance of one foot from a standard candle light source. One footcandle is equal to one lumen per square foot.

Glare: A sensation produced by light which is considerably greater than the light to which the eyes are accustomed.

Indirect lighting: A lighting system in which luminaires distribute 90 to 100 percent of the light emitted in an upward direction.

Lamp: Any man-made source of light.

Lumen: The amount of light falling on a unit surface, all points of which are a unit distance from a uniform light source of one footcandle. Essentially, it expresses the amount of light output from a source.

Luminaire: A fixture designed to hold lamps and produce a specific lighting effect on the area to be lighted.

Reflectance: The ratio of the light reflected from an object to the light falling onto that object.

Work plane: A level at which work is usually performed. A horizontal plane 30 inches above the floor is used for lighting design unless otherwise specified.

5.3 Light Characteristic

To have a better understanding of lighting systems requires a knowledge about the characteristics of light. Light is a visible form of radiation that is actually a narrow band of frequencies which is part of the electromagnetic spectrum. The electromagnetic spectrum includes bands of frequencies for radio, television, radar, infrared radiation, visible light, ultraviolet light, x-rays, gamma rays, and many other frequencies. The types of radiation differ with respect to their frequencies or wavelengths.

The human eye responds to electromagnetic waves in the "visible-light" band of frequencies. Each color of light has a different frequency or wavelength. In order of increasing frequency (or decreasing wavelengths),

the basic colors are red, orange, yellow, green, blue, and violet. The human eyes perceive various degrees of brightness as a result of their response to the wavelengths of light (3:93).

5.4 Basic Terminology

Some important terms used in lighting systems were discussed in section 5.2. However, there are several basic terms associated with light that require further discussion. The unit of light intensity is a standard light source called "candlepower". The intensity of light is expressed using this unit. The amount of light falling on a unit surface, all points of which are a unit distance from a uniform light source of one candlepower, is one "lumen". The illumination of a surface is the number of lumens falling on it per unit area. The unit of illumination is the "footcandle" (lumens per square foot).

5.5 Calculating Costs

All electrical costs are figured on a per kilowatt-hour basis (called kwh). That is, if a 100-watt bulb is burned for 10 hours, 1,000 watts (10 hours times 100 watts [100 x 10 = 1,000]) which equals one kilowatt hour has been consumed. The amount of energy used is registered on an electric meter usually located on the side of the house. Naturally the meter is constantly changing, and it is normally read monthly by the electric company. The older month's reading is subtracted from the newer reading and the result is the amount of kwh consumed over that period.

Many electric companies bill the homeowner on a sliding scale. That is, the first 30 kwh may cost $5 while the next 200 will cost somewhat less. Then again, some companies have special rates for those who use "off-peak" hours of electricity. Some companies also have summer and

winter rates. Whatever the case may be, even a rough estimate of what each average kwh costs can be an incentive to conserve electrical energy use.

According to estimates, the average family of four uses 1,200 to 2,400 kwh monthly. This figure can and will vary according to each family's size and lifestyle, as well as whether or not such items as electric heat, hot water, stoves, etc. are included on the electric budget. Burning a 100-watt bulb for ten hours on the exterior of a home each night means that 365 kwh are consumed for that light. If it is replaced with a 50-watt bulb, the wattage and therefore the energy output is cut in half. This saves half the money or about $12.77 each year on just one light based on electricity costing seven cents per kwh. Multiplying this type of savings throughout the house, can add up dollar savings quickly (2:62).

5.6 Wattage Reduction

Many people think that by purchasing lower wattage bulbs, they automatically reduce the amount of light it gives. Often this is not true at all. A watt is defined as the amount of electricity consumed by the bulb. "Lumens" are the real measure of the amount of brightness or light emitted by the bulbs, and bulb life tells approximately how long the bulb will last before burning out. All this information is required to be on the label of each bulb package. The amount of light (lumens) can now be compared to the amount of energy it will costs (watts).

Consumers should look carefully at long-life bulbs. These bulbs only furnish about 80 percent of the lumens for the same wattage.

Table 5.1 shows this relationship between standard and long-life bulbs. It then becomes a trade-off between more light for the money or more bulb-life money expended on electricity. These long-lasting bulbs may want to be considered for hard-to-reach places such as high hall lights or post lanterns (2:62).

Again, buyer beware! Although one 150-watt bulb offers 2,880 lumens, two 75-watt bulbs (equal energy output) only offer 2,380 lumens. Larger wattage bulbs are generally more efficient and produce more lumens per watt than smaller bulbs. It generally requires six 25-watt bulbs to give the same amount of light as only one 100-watt bulb (2:62).

To conserve energy in electrical lighting in the home a thorough understanding of the relationships between watts and lumens, the options on various light sources, and the amount of lumens needed for certain activity areas of the home should be acquired. A decision can then be made as to certain areas in the house being overlighted and if they can now be cut down both in wattage and in lumens.

There are basically three types of light bulbs on the market for the consumer to choose from in order to conserve energy. The basic bulbs are fluorescent, high intensity discharge HID) and incandescent.

Table 5.1 Lumen outputs of standard and long-life incandescent bulbs.

	Watts	Lumens	Bulb life (hrs)	Lumens/watt
Standard bulbs	100	1740	750	17.4
	75	1180	750	15.7
Long-life bulbs	100	1690	1150	16.9
	100	1490	2500	14.9
	100	1470	3000	14.7
	92	1490	2500	16.2
	90	1290	3500	14.3

Source (2:63).

5.7 Incandescent Lighting

Incandescent lighting is a common type of lighting that has long been on the market and can be purchased in virtually every supermarket across the country.

Incandescent lamps usually have thin tungsten filaments (see Figure 5.1) which are connected through the lamp base to an electrical power source. When an electric current passes through the filament, the temperature of the filament rises to between 3000 and 5000 (degrees) F, and at this temperature range, the tungsten produces a high-intensity white light. During the manufacture of an incandescent light, the air is removed from the glass envelope to prevent the filament from burning, and an inert gas is added (3:94).

As lights get older, their light output is reduced. Typically, just before an incandescent lamp burns out, its light output is less than 85 percent of its original output. A decrease in the voltage of the power system will also reduce the light output. A one percent decrease in voltage will cause a three percent decrease in light output (approximately) (3:94).

This popular bulb is the most expensive one to use (incandescent lamps have relatively low efficiency and a short life span) but is considered as the most versatile for the home. It also permits close control. Two key ways to conserve electrical output when using incandescent bulbs are: (1) use a three-way light bulb wherever possible, and (2) install dimmer switches. Both of these suggestions work on the same principle. By using lower or dimmer lights whenever possible, less watts and therefore less energy are consumed.

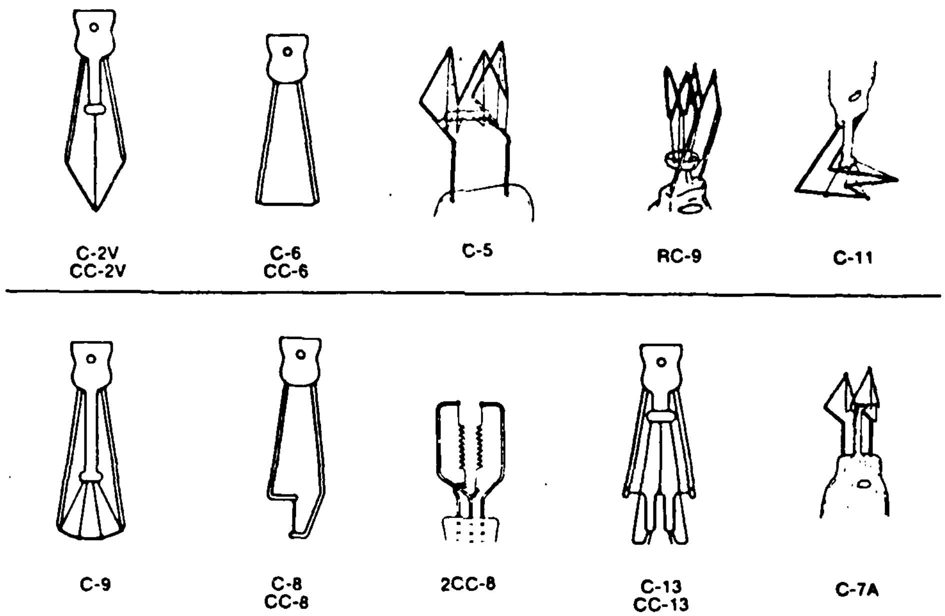


Figure 5.1 Incandescent lamp filament designs (3:96).

Three different watts and lumen intensities are made available by the use of a three-way bulb. It is the most economical of the incandescents because the wattage can be controlled very easily. A three-way bulb is installed in a socket that is geared for it and the switch turns to three different light intensities (such as 50-100-150) always starting from the lowest to the highest. If the light needs are satisfied by one of the lower intensities, energy is obviously conserved. The three-way bulbs often avoid the expense of installing other fixtures around that area which may need higher or lower lighting. Any multipurpose light fixture will eventually pay for itself and save money.

The dimmer switch, which has numerous settings, from off to full bright can be installed in the wall or attached to light cords. These units are easily installed. Although the dimmer costs about $5 to $10,

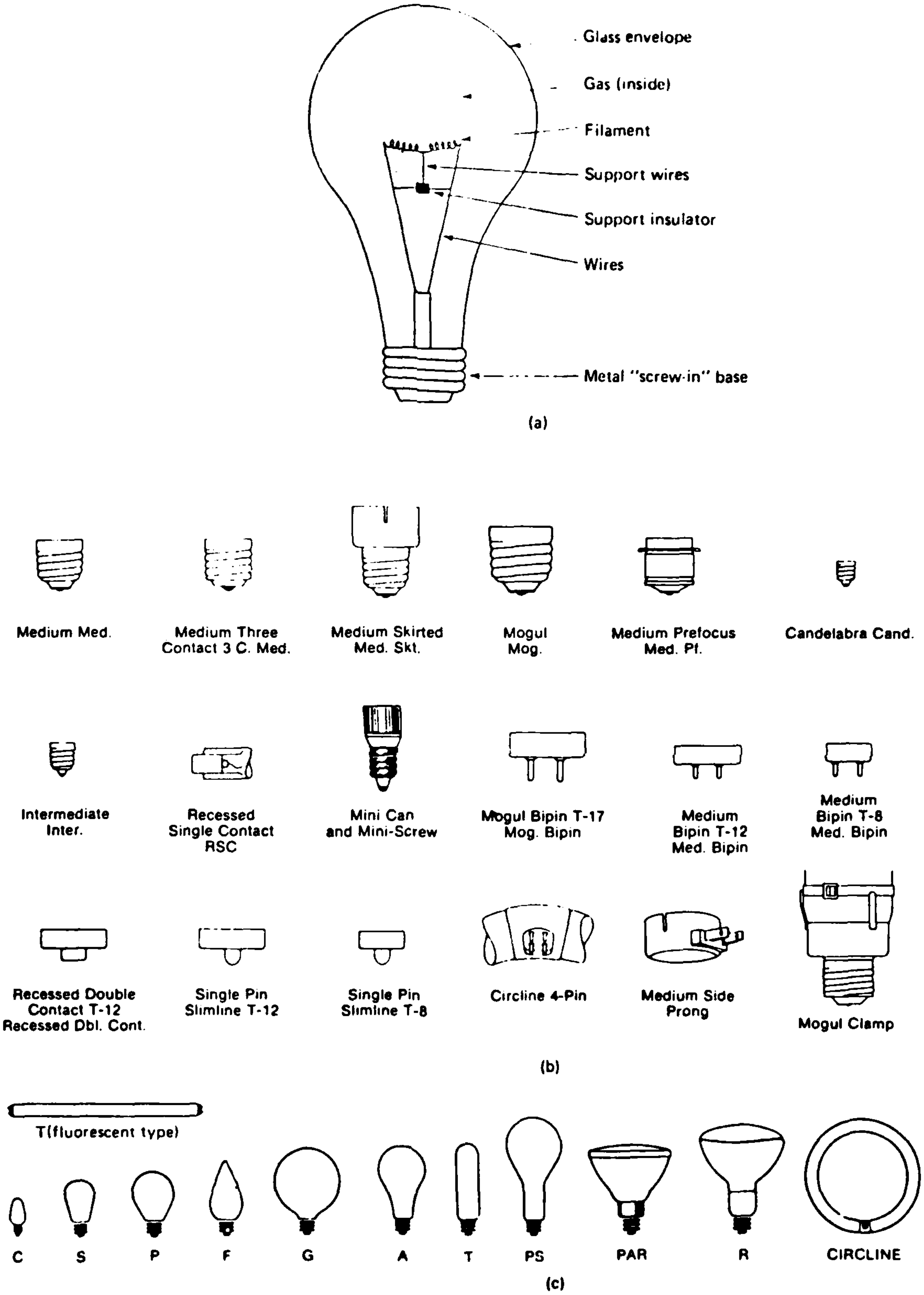


Figure 5.2 (a) Incandescent lamp; (b) common lamp bases; (c) common bulb designations (3:95).

the switch can almost pay for itself in a year if used regularly. It certainly allows the setting of the mood and the saving of money and energy at the same time (2:64).

5.8 Fluorescent Lighting

Fluorescent lights are probably the cheapest source of lumens available for the money. They produce up to five times as much light as, last 20 times longer than, and give off less waste heat than their incandescent counterparts. They may cost more than incandescent initially, but pay for themselves in the long run (18:22).

Fluorescent lights are tubular bulbs with a filament at each end, but there is no electrical connection between the two filaments. The fluorescent lamp operates as follows: The tube is filled with mercury vapor; when an electrical current flows through the two filaments, a continuous arc is formed between them by the mercury vapor. High-speed electrical particles passing between the filaments collide with the mercury atoms, producing ultraviolet radiation. The inside of the tube has a phosphor coating which reacts with this ultraviolet radiation to produce visible light (see Figure 5.3). When the ends of a fluorescent lamp become heavily darkened, the lamp should be replaced because it is near the end of its life. Some darkening, however, on the ends is normal (19:189).

As mentioned earlier, fluorescent lights produce more light per watt than do incandescent lights; therefore, they are cheaper to operate. Since the illumination is produced by a long tube, there is also less glare and the light produced by fluorescent bulbs is similar to natural daylight. The light is whiter and the operating temperature is much less with

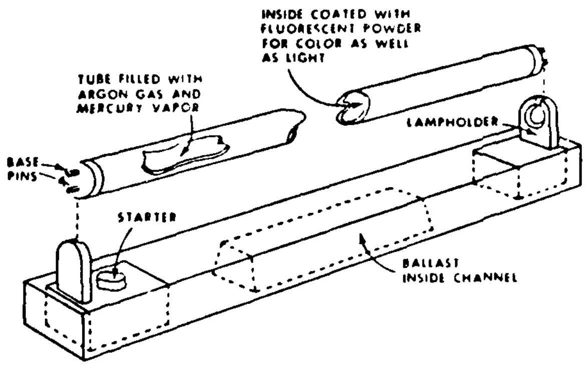
fluorescent lights than with incandescents. Various sizes and shapes of fluorescent lights are available. The bulb sizes are expressed in eighths of an inch with two common sizes being T-12 and T-8. (A T-12 bulb is 1½ in. - 12/8.) Common lengths are 24, 48, 72, and 96 inches (3.97).

Table 5.2 Energy comparison for incandescent bulbs and fluorescent tubes.

	Incandescent bulb	*Deluxe fluorescent tube*	*Fluorescent Advantages*
Watts	75	30 (44 total input watts)	31-watt (or 41 percent) energy saving
Bulb life	750 hours	15,000 hours	lasts 14,250 hours more (or 20 times longer)
Light emitted	1180 lumens	1530 lumens	350 more lumens, or 30 percent more light

Source (2:63).

Ballasts are the devices used to cause fluorescent lights to start and are therefore necessary to the operation of fluorescent lighting systems. A ballast is usually an enclosed coil of many turns of wire connected into the electrical circuit of a lamp. The ballast supplies the necessary voltage surge to develop an arc discharge to ignite the mercury gas within the lamp tube. A ballast also limits the current flow through the lamp and thus acts as a protective device to prevent destruction of the lamp (3:97).



The fluorescent phosphor coating on the inside of the tube is activated by electric energy passing through the tube; light is given off. The starter in standard starter-type fixtures permits preheating of the electrodes in the ends of the tube to make it easier to start. The ballast limits the current to keep the tube functioning properly. The channel holds ballast and wiring and spaces the lampholders.

(Dept. of Agriculture).

Figure 5.3 Fluorescent lamp (2:63).

5.9 Vapor Lighting

Vapor lighting is another popular form of lighting. The mercury-vapor light is one of the most common types of vapor lights. These vapor lights are filled with a gas that produces a characteristic color. For instance, mercury vapor produces a greenish-blue light and argon a bluish-white light. Gases are often mixed to produce various color combinations for vapor lighting.

A mercury-vapor lamp consists of two tubes with an arc tube placed inside an outer bulb with the inner tube containing mercury. When a voltage is applied between the starting probe and an electrode, an arc is started between them. The arc current is limited by a series resistor; however, the current is enough to cause the mercury in the inner tube to ionize. Once the mercury has ionized, an intense greenish-blue light is produced. Mercury-vapor lights are compact, long-lasting, and easy to maintain. They are used to provide a high-intensity light output. At low voltages, mercury is slow to vaporize, so these lamps require a long starting time (sometimes four to eight minutes). Other vapor lighting operate on similar principles (3:98).

5.10 High Intensity Discharge Lamps (HID)

Several types of high intensity discharge (HID) lamps are in use today. These are a classification of lamps which produce light when a high-voltage arc passes through a vapor-filled tube. These units can give from 2 to 5 times as much light as an incandescent bulb for the same amount of watts. Until recently, HID lamps were used primarily in industries where color qualities were not important. They now have improved color characteristics and are available in a variety of sizes.

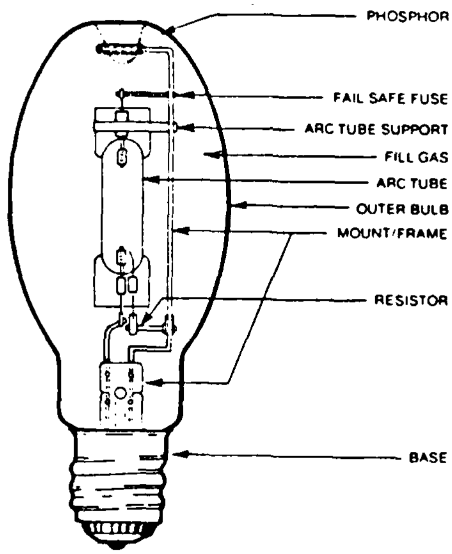


Figure 5.4 Mercury-vapor lamp (3:98).

They are small lamp fixtures directing high intensity beams of light on a small area and therefore are good for task and area lighting. The HID lights are easy to maintain - they last 10 to 30 times longer than similar incandescent bulbs and they come in colors and tones similar to incandescent. Many types of lamps fail under the general category of HID lamps.

5.11 Metal-Halide Lamps

Metal-halide lamps are essentially mercury-vapor lamps that have been altered by the addition of different compounds in the enclosed portion of the lamp. The color characteristics of metal-halide lamps are thus quite different from those of mercury-vapor lamps (3:99).

CHAPTER SIX
COMPUTERIZED ENERGY EFFICIENCY

6.1 Computer Technology

As discussed in the previous chapters, many techniques have been developed to conserve energy in the home as well as many other areas. For example, more and better insulation, thermal-paned windows, and also energy-efficient appliances, heat pumps, etc., have been introduced. With the advent of computer technology one could guess that it would be only a short time before it would be put to use designing homes that were much more energy efficient.

This chapter concentrates on the use of the computer to determine the cooling requirements of a home. A dialogue type comuter program as presented in Rodale's August 1984 New Shelter magazine with some modifications by this author is used to demonstrate the usefulness of computers when attempting to conserve energy. In this chapter, the program will be compared to the results obtained by a much more expensive and sophisticated program called BLAST used by the University of Florida Energy Park.

6.2 Determining Cooling Loads

This computer program calculates the size of air conditioning systems required to cool homes of various types of construction. It first considers the amount of heat gained through walls, roofs, windows, insulation, etc. It then takes this input to calculate the home's peak

cooling load which is the amount of heat in British Thermal Units (BTU's) per hour that the air conditioning system would have to remove from the home under worst-case conditions (typically 95 degrees Fahrenheit outside air temperature with 80 percent relative humidity) (20:40).

6.3 Factors

There are two factors that are an integral part of the program that must be supplied by the user - a climate factor and an air-conditioning running time (hr/yr) factor. These factors differ according to the various cooling zones throughout the country. A climate factor of 1.15 and a running time factor of 1250 hr/yr correspond with the cooling zone in which Gainesville, Florida is located (20:41).

6.4 Information Required

During the program run questions appear that the user must respond to. The following pages attempt to provide a better understanding of how the program analyzes this input.

"NUMBER OF ROOFS ABOVE VENTED ATTICS?"

"WHAT IS THE SQUARE FOOT AREA?"

If the home is a typical home with one roof and a vented attic, the program will ask for information about that one roof. However, if it is an unusual home with more than one such roof (for example, an old home onto which an addition has been built), the program will ask information about each of the roofs (21:60).

"HOW MUCH SUN DOES IT GET"

(10=UNSHADED, 0=FULLY SHADED)

This is the shading factor. This factor accounts for the reduction in the cooling load that results from keeping direct sunlight from shining on the roof.

"NUMBER OF CATHEDRAL CEILINGS OR ROOFS ABOVE UNVENTED ATTICS?"

If the home has a cathedral ceiling or an attic with no ventilation openings or louvers, the square-foot area of the ceiling must be entered in the space provided.

"WHAT IS ITS R-VALUE (MIN. = 3)?"

This number is used to determine the insulation factor of the roof's insulation (in other words, the R-value (discussed in Chapter Two) of the insulation is lowered by 20 percent to account for inevitable "thermal bridging" - heat that bypasses the insulation, for example through rafters) (20:40).

"NORTH-FACING EXTERIOR WALL"

"WHAT IS THE SQUARE FOOT AREA?"

The square-foot area of the exterior walls (those asked for) of the home must be entered in the spaces provided. Included is the area of any doors, but the area of windows are excluded here because they are handled separately. Earth-bermed walls and below-grade basement walls are not considered here either because the heat transferred through such walls has very little effect on peak cooling loads.

"PARTITION WALLS BETWEEN HOT AND COOL?"

These are partition walls (interior) that separate any nonconditioned rooms from the main living space. Nonconditioned spaces are those parts of the house that are not cooled mechanically. (For example, an attached garage that heats up during the day is considered a nonconditioned space). Nonconditioned spaces can contribute significant heat gain, especially if the walls between these spaces and the rest of the house are uninsulated (20:43).

"NUMBER OF FLOOR TYPES BETWEEN CONDITIONED & UNCONDITIONED AREAS?"

"FACTOR"

"SLAB ON GRADE = .1"

"FLOOR ABOVE OPEN CRAWL SPACE = 1"

"FLOOR ABOVE CLOSED CRAWL SPACE OR BASEMENT = 0"

"FLOOR ABOVE NON-AIRCONDITIONED ROOM = .9"

The area of any floors that separate conditioned from nonconditioned spaces in the home must be entered. This area includes floors above a garage or open crawl space; it also includes floors on grade that have no perimeter insulation. The floor factor that applies to each of the floors must then be entered.

"HOW AIRTIGHT IS THE HOME?"

(10 = VERY TIGHT, 0 = VERY LEAKY)

This factor considers the amount of air infiltration (number of air changes per hour) of the home's conditioned space.

"TOTAL AREA OF ALL WINDOWS?"

"TYPE THE APPROPRIATE FACTORS:"

"-SINGLE GLAZED WINDOWS = 1, 1"

"-DOUBLE GLAZED WINDOWS = .5, .8"

"-TRIPLE GLAZED WINDOWS = .33, .65"

The first factor given for each type of window considers heat gained through conduction. The second factor considers heat gained from direct sunlight. The program goes on to ask which direction the windows face since the direction is an important part of the calculation of heat gain (20:41).

"TOTAL WATTAGE OF ALL ELECTRICAL DEVICES?"

(MIN. = 600)

The total wattage of all electrical equipment, excluding air conditioners, that is usually used in the home during summer afternoons and evenings should be entered here. This amount should be at least 600 watts to account for the waste heat from the refrigerator (about 300 watts), water heater (about 200 watts), and a few lights. For a large family that uses a lot of electrical equipment, the total may be 1000 watts or more (20:43).

"THERMAL MASS IN THE HOUSE?"

(10 = A LOT, 1 = VERY LITTLE)

This number is an estimate. If the house has fully earth-bermed walls and an earth-sheltered roof, this number may be as high as ten. Other examples are: a wood-frame house - five or smaller; a wood-frame house with

exterior masonry veneer or a solid masonry house - seven; a house with masonry interior walls, floors, or other interior thermal mass - eight (20:40).

"EER's OF THE TWO AIR CONDITIONERS?"

EER stands for energy-efficiency rating; the higher the number, the better. Numerically, the EER tells how much cooling (in BTU/HR) a given unit provides per watt of electricity used.

6.5 Computer Output

This program proved to be very accurate considering its simplicity and its lack of sophistication. It calculated a peak cooling load of 32,723 BTU/HR as compared to the BLAST calculation of 32,758 BTU/HR (a 0.1 percent difference) using the input data provided by the University of Florida Energy Park. Of course BLAST has many more capabilities but to calculate peak cooling loads the Rodale program is quite sufficient.

6.6 Calculating Pay-Back Period

Because of the many variables used in this program it can also be used to actually design an energy efficient home or to improve the efficiency of an existing home. This is accomplished by simply changing the variables, preferably one at a time (the program allows this), to determine what effect it has on the cooling requirements. For example, adding extra insulation may or may not cut the cooling requirements significantly. The program can be rerun several times until the desired outcome is achieved. The advantage of using this computer program is that the information is available almost immediately. By comparing

the electric bill savings per year provided by the computer, the consumer can calculate the simple pay-back period and decide if that extra energy savings are really worthwhile.

CHAPTER SEVEN
SUMMARY AND CONCLUSIONS

Energy conservation in the home has become very important to homeowners. One of the reasons for this is that when energy is saved, so is money. Since the 1973 oil embargo, prices for energy usage have steadily increased. An uncertainty exists now as to how long the supplies of energy will last and because of the law of supply and demand homeowners are concerned about the future costs of energy.

New homes that are being built today feature energy saving construction and energy saving appliances. "Energy Conservation" homes have become big business. Consumers shy away from homes that drain their pocketbooks because of energy wastefulness. Building material stores advertise such things as thermopane windows, high-quality insulation, ventilation systems, ceiling fans, and the like. People are buying these items in large numbers to conserve energy usage in their homes. The government has even entered the picture by offering tax saving incentives discussed in Chapter Two. No longer do the days exist when little concern was shown for the amount of energy consumed to heat or cool a home.

This report has attempted to discuss many of the techniques used to save energy and money in the home but is not all-inclusive. For example, appliances and heating, venting, and air conditioning (HVAC) systems were not included. These topics are obviously important but were not a part of this report for two reasons. One is that they would have increased

the length of the report more than was desired. Secondly, many if not all of the appliances and HVAC systems on the market today are manufactured with energy conservation in mind and consequently are much more efficient than those of days gone by.

The computer program presented in Chapter Six is not the most sophisticated one available but is very useful in determining the capacity air conditioning system a home may require. The program has some limitations in that it does not consider the many different living habits of families throughout the country, for example, the temperature they set their thermostats to in order to feel comfortable. The program, however, does give an indication of how making changes to a home (for example, replacing single-glaze windows with triple-glaze windows) can result in a reduction in energy consumption and therefore, a reduction in the monthly utility bills. From that data it is then possible to determine a simple pay-back period from which the consumer can make a decision as to whether a change will be beneficial financially.

Making changes to existing homes can be very expensive and should be considered carefully. Thousands of dollars can be spent on insulation and windows and doors, but if the house has many air leaks and an inefficient HVAC system, the money may well have been spent on some other modification to the home.

Energy conservation in the home is here to stay. Newer and better techniques to conserve energy will continue to appear on the market, and builders will continue to use these techniques and to look for better ideas because the homeowner today will settle for nothing else.

APPENDIX A

PROGRAM LISTING

```
 80 DIM A$(1),D$(29),S$(7):LET CF=1.15:LET RT=1250

>100 GOSUB 780

>120 LET R=0:LET C=0:PRINT "NUMBER OF ROOFS ABOVE VENTED ATTICS";:LPRINT
"NUMBER OF ROOFS ABOVE VENTED ATTICS":INPUT VA:LPRINT VA:IF VA=0 THEN 160

>140 FOR Y=1 TO VA:GOSUB 780:PRINT "ROOF #";Y:LPRINT "ROOF #";Y:GOSUB
800:S$="DOES IT":GOSUB 820:GOSUB 1260:GOSUB 900:LET V=44:GOSUB 920:LET
R=R+X:NEXT Y

>160 GOSUB 780:PRINT "NUMBER OF A) CATHEDRAL CEILINGS OR":LPRINT "NUMBER
OF A) CATHEDRAL CEILINGS OR":PRINT "B) ROOFS ABOVE UNVENTED ATTICS";:LPRINT
"B) ROOFS ABOVE UNVENTED ATTICS";:INPUT UA:LPRINT UA:IF UA=0 THEN GOTO 200

>180 FOR Y=1 TO UA: GOSUB 780:PRINT "CEILING OR ROOF #";Y:LPRINT "CEILING
OR ROOF #",Y:GOSUB 800:S$="DOES IT":GOSUB 820:GOSUB 1260:GOSUB 900: LET
V=48: GOSUB 920:LET C=C+X:NEXT Y

>200 IF ZZ=1 THEN GOTO 500

>220 LET W=0:GOSUB 780:FOR Y=1 TO 4:GOSUB 1000:PRINT D$;"-FACING EXTERIOR
WALL:":LPRINT D$;"-FACING EXTERIOR WALL:":GOSUB 800:S$="DOES IT":GOSUB
820:GOSUB 1260:GOSUB 900:GOSUB 920:LET W=W+X:GOSUB 780:NEXT Y:IF ZZ=1
THEN 500

>240 LET I=0:GOSUB 780:PRINT "PARTITION WALLS BETWEEN HOT AND COOL";:LPRINT
"PARTITION WALLS BETWEEN HOT AND COOL";:INPUT IW:LPRINT IW:IF IW=0 THEN
GOTO 280

>260 FOR Y=1 TO IW:GOSUB 780:PRINT "WALL #";Y:LPRINT "WALL #";Y:GOSUB
800:GOSUB 900:LET V=12: LET SF=1:GOSUB 920:LET I=I+X:NEXT Y

>280 IF ZZ=1 THEN 500

>300 LET F=0:GOSUB 780:PRINT "NUMBER OF FLOOR TYPES BETWEEN CONDI-":LPRINT
"NUMBER OF FLOOR TYPES BETWEEN CONDI-":PRINT "TIONED AND UNCONDITIONED
AREAS";:LPRINT "TIONED AND UNCONDITIONED AREAS";:INPUT FL:LPRINT FL:IF
FL=0 THEN 340

>320 FOR Y=1 TO FL:GOSUB 780:PRINT "FLOOR TYPE #";Y:LPRINT "FLOOR TYPE
#";Y:GOSUB 800:GOSUB 960:GOSUB 900:LET V=20:GOSUB 920:LET F=F+X:NEXT Y

>340 IF ZZ=1 THEN 500

>360 GOSUB 780:PRINT "TOTAL FLOOR AREA OF CONDITIONED SPACES":LPRINT
"TOTAL FLOOR AREA OF CONDITIONED SPACES":INPUT FA:LPRINT FA:PRINT:LPRINT:
PRINT"HOW AIRTIGHT IS THE HOME?":LPRINT "HOW AIRTIGHT IS THE HOME?"
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>365 PRINT "(10 = VERY TIGHT, 0 = VERY LEAKY)":LPRINT "(10 = VERY TIGHT,
0 = VERY LEAKY)":INPUT AC: LPRINT AC: LET AC=1.3-(AC*.11):LET A=FA*AC*1.6:
IFZZ=1 THEN 500

>400 LET WS=0:GOSUB 780:PRINT "TOTAL AREA OF ALL WINDOWS"::LPRINT "TOTAL
AREA OF ALL WINDOWS";:INPUT AW:LPRINT AW:GOSUB 1100:LET WC=AW*16*GA:FOR
Y=1 TO 4:GOSUB 780: GOSUB 1140:PRINT "WINDOWS THAT FACE ":LPRINT "WINDOWS
THAT FACE "

>401 PRINT D$;":":LPRINT D$;":":GOSUB 800:LET S$="DO THEY":GOSUB 820:LET
SF=.3+(SF*.07):GOSUB 940

>402 LET WS=WS+X:NEXT Y:IF ZZ=1 THEN 500

>440 GOSUB 780:PRINT "TOTAL WATTAGE OF ALL ELECTRICAL DEVICES":LPRINT
"TOTAL WATTAGE OF ALL ELECTRICAL DEVICES":PRINT "(MIN.=600)";:LPRINT
"(MIN. = 600)";:INPUT WT:LPRINT WT:LET WT=WT*3:IF ZZ=1 THEN 500

>460 GOSUB 780:PRINT "NUMBER OF RESIDENTS(MIN.=2)";:LPRINT "NUMBER OF
RESIDENTS (MIN. = 2)";:INPUT P:LPRINT P:LET P=P*600:IF ZZ=1 THEN 500

>480 GOSUB 780:PRINT "THERMAL MASS IN THE HOME ?":LPRINT "THERMAL MASS IN
THE HOME ?":PRINT "(10=A LOT,1=VERY LITTLE)":LPRINT "(10 = A LOT, 1 = VERY
LITTLE)":INPUT TM:LPRINT TM:LET TM=1.0333-(TM*.0333)

>500 LET HG=(R+C+W+I+F+A+WC+WS)*CF:LET CL=(HG+WT+P)*TM:LET EC=CL*RT/1000

>520 GOSUB 780:PRINT "TOTAL HEAT GAIN=":PRINT " ";HG;"BTU/HR":PRINT:LPRINT:
PRINT"PEAK COOLING LOAD=":LPRINT "PEAK COOLING LOAD = ":PRINT " ";CL;"BTU/
HR":LPRINT " ";CL;"BTU/HR":GOSUB 1240:IF ZZ=1 THEN 600

>540 GOSUB 780:PRINT "COST OF ELECTRICITY PER KWH? NOTE: ":LPRINT "COST OF
ELECTRICITY PER KWH? NOTE: ":PRINT ".10=10 CENTS, .09=9 CENTS, ETC.":INPUT
KW: LPRINT KW: IF ZZ=1 THEN GOTO 600

>560 GOSUB 780:PRINT "EER'S OF TWO AIR CONDITIONERS? GIVE ":LPRINT "EER'S
OF TWO AIR CONDITIONERS? ":PRINT "HIGHER EER FIRST. (TO SKIP, TYPE 0.)":
PRINT:LPRINT:PRINT "AIR CONDITIONER #1:";:LPRINT "AIR CONDITIONER #1:";:
INPUT EA:LPRINT EA:IF EA =0 THEN GOTO 660

>580 PRINT:LPRINT:PRINT "AIR CONDITIONER #2:";:LPRINT "AIR CONDITIONER
#2:";:INPUT EB:LPRINT EB

>600 LET AA=EC/EA:LET AB=EC/EB:LET CA=AA*KW:LET CB=AB*KW:GOSUB 780:PRINT
 "ELECTRICAL USE = ":LPRINT "ELECTRICAL USE = ": PRINT " #1:";AA;"BTU'S:
LPRINT " #1:";AA;"BTU'S":PRINT:LPRINT:PRINT"ANNUAL OPERATING COST = "

>602 LPRINT "ANNUAL OPERATING COST = ":PRINT "#1:$";CA:LPRINT "#1:$";CA:
PRINT "#2:$";CB:LPRINT "#2:$";CB:GOSUB 1240:IF ZZ=1 THEN 640

>620 GOSUB 780:PRINT "WHAT DO THE AIR CONDITIONERS COST?":LPRINT "WHAT DO
 THE AIR CONDITIONERS COST?":PRINT:LPRINT:PRINT"AIR CONDITIONER #1:";:
LPRINT "AIR CONDITIONER #1:";:INPUT MA:LPRINT MA:PRINT:LPRINT:PRINT "AIR
 CONDITIONER #2:";:INPUT MB

>622 LPRINT "AIR CONDITIONER #2:";:LPRINT MB
```

```
>640 LET PD=MA-MB:LET SV=CB-CA:GOSUB 780:PRINT "AIR CONDITIONER #1 COSTS $";SV:
PRINT "LESS TO OPERATE.":PRINT:PRINT"RETURN ON INVESTMENT=";(SV/PD)*100;"%":

>642 LPRINT "AIR CONDITIONER # 1 COSTS $";SV: LPRINT "LESS TO OPERATE.":
LPRINT:LPRINT"RETURN ON INVESTMENT = "; (SV/PD)*100;"%":GOSUB 1240

>660 GOSUB 780:PRINT "WHICH WOULD YOU LIKE TO CHANGE?":PRINT:PRINT"1)ROOF
 HEAT GAIN":PRINT "2)EXTERIOR WALL HEAT GAIN":PRINT"3)INTERIOR WALL HEAT
 GAIN":PRINT"4)FLOOR HEAT GAIN"

>680 PRINT "5)AIR TIGHTNESS OF HOME":PRINT "6)WINDOW HEAT GAIN":PRINT
 "7)ELECTRICAL USE":PRINT "8)NUMBER OF RESIDENTS":PRINT "9)AMOUNT OF THER
MAL MASS"

>700 PRINT "10)COST OF ELECTRICITY":PRINT "11)AIR CONDITIONERS":PRINT:
PRINT"12)NONE OF THE ABOVE":LET ZZ=1:PRINT:PRINT"CHOOSE A NUMBER, THEN
 PRESS ENTER":INPUT CH

>720 GOSUB 780:ON CH GOTO 120,220,240,300,360,400,440,460,480,540,740,1280

>740 LET ZZ=2:GOTO 560

>780 CLS:RETURN

>800 PRINT:PRINT "WHAT IS THE SQUARE FOOT AREA";:INPUT SQ

>802 LPRINT:LPRINT"WHAT IS THE SQUARE FOOT AREA";:LPRINT SQ:RETURN

>820 PRINT:PRINT "HOW MUCH SUN ";S$;" GET?":PRINT "(10=UNSHADED, 0=FULLY
 SHADED)":INPUT SF

>822 LPRINT:LPRINT "HOW MUCH SUN ";S$;" GET?":LPRINT "(10 = UNSHADED, 0 =
 FULLY SHADED)":LPRINT SF: RETURN

>900 PRINT:PRINT "WHAT IS ITS R-VALUE(MIN.=3)";:INPUT RF

>902 LPRINT:LPRINT "WHAT IS ITS R-VALUE (MIN. = 3)";:LPRINT RF:LET RF=RF*.8:
RETURN

>920 LET X=SQ*V*SF/RF:RETURN

>940 LET X=SQ*V*GB*SF:RETURN

>960 PRINT:PRINT"TYPE THE APPROPRIATE FACTOR:":PRINT:PRINT"-SLAB ON GRADE =
 .1":PRINT"-FLOOR ABOVE OPEN CRAWLSPACE = 1":PRINT"-FLOOR ABOVE CLOSED
 CRAWLSPACE OR":PRINT"BASEMENT = 0":PRINT"-FLOOR ABOVE NON-AIR CONDITIONED":
PRINT "ROOM = .9"

>962 LPRINT:LPRINT "TYPE THE APPROPRIATE FACTOR:":LPRINT:LPRINT"-SLAB ON
 GRADE = .1":LPRINT"-FLOOR ABOVE OPEN CRAWLSPACE = 1":LPRINT"-FLOOR ABOVE
 CLOSED CRAWLSPACE OR":LPRINT"BASEMENT = 0":LPRINT"-FLOOR ABOVE NON-AIR
 CONDITIONED"

>964 LPRINT "ROOM = .9"

>980 PRINT:PRINT"FACTOR:";:INPUT SF
```

```
>982 LPRINT:LPRINT "FACTOR:";:LPRINT SF: RETURN

>1000 ON Y GOTO 1020,1040,1060,1080

>1020 D$="NORTH":V=18:RETURN

>1040 D$="EAST":V=28:RETURN

>1060 D$="WEST":V=28:RETURN

>1080 D$="SOUTH":V=24:RETURN

>1100 PRINT:PRINT"TYPE THE APPROPRIATE FACTORS:":PRINT:PRINT"-SINGLE GLAZED
 WINDOWS = 1,1":LPRINT"-DOUBLE GLAZED WINDOWS = .5,.8":PRINT "-TRIPLE
 GLAZED WINDOWS = .33,.65"

>1102 LPRINT:LPRINT"TYPE THE APPROPRIATE FACTORS:":LPRINT:LPRINT"-SINGLE
 GLAZED WINDOWS = 1,1":LPRINT"-DOUBLE GLAZED WINDOWS = .5,.8":LPRINT"-
TRIPLE GLAZED WINDOWS =.33,.65"

>1120 PRINT:PRINT "FACTOR #1:";:INPUT GA:LPRINT:LPRINT"FACTOR #1:";:LPRINT
 GA:PRINT:LPRINT:PRINT "FACTOR #2:";:LPRINT "FACTOR #2:";:INPUT GB:LPRINT GB:
 RETURN

>1140 ON Y GOTO 1160,1180,1200,1220

>1160 D$="DUE NORTH":V=16:RETURN

>1180 D$="EAST, SOUTH, OR SOUTHEAST":V=80:RETURN

>1200 D$="WEST, SOUTHWEST, OR NORTHWEST":V=140:RETURN

>1220 D$="NORTHEAST":V=50:RETURN

>1240 PRINT:PRINT"<ENTER A KEYSTROKE>";:INPUT A$:RETURN

>1260 SF = .7 + (SF*.03):RETURN

>1280 GOSUB 700:PRINT "<END>":END
```

APPENDIX B

PROGRAM OUTPUT

```
NUMBER OF ROOFS ABOVE VENTED ATTICS?
ANS: 1

ROOF # 1
WHAT IS THE SQUARE FOOT AREA?
ANS: 1540
HOW MUCH SUN DOES IT GET?
(10 = UNSHADED, 0 = FULLY SHADED)
ANS: 10
WHAT IS ITS R-VALUE (MIN. = 3)?
ANS: 30

NUMBER OF A) CATHEDRAL CEILINGS OR
B) ROOFS ABOVE UNVENTED ATTICS?
ANS: 0

NORTH-FACING EXTERIOR WALL:
WHAT IS THE SQUARE FOOT AREA?
ANS: 224
HOW MUCH SUN DOES IT GET?
(10 = UNSHADED, 0 = FULLY SHADED)
ANS: 10
WHAT IS ITS R-VALUE (MIN. = 3)?
ANS: 19

EAST-FACING EXTERIOR WALL:
WHAT IS THE SQUARE FOOT AREA?
ANS: 355
HOW MUCH SUN DOES IT GET?
(10 = UNSHADED, 0 = FULLY SHADED)
ANS: 10
WHAT IS ITS R-VALUE (MIN. = 3)?
ANS: 19

WEST-FACING EXTERIOR WALL:
WHAT IS THE SQUARE FOOT AREA?
ANS: 325
HOW MUCH SUN DOES IT GET?
(10 = UNSHADED, 0 = FULLY SHADED)
ANS: 10
WHAT IS ITS R-VALUE (MIN. = 3)?
ANS: 19

SOUTH-FACING EXTERIOR WALL:
WHAT IS THE SQUARE FOOT AREA?
ANS: 194
HOW MUCH SUN DOES IT GET?
(10 = UNSHADED, 0 = FULLY SHADED)
ANS: 10
WHAT IS ITS R-VALUE (MIN. = 3)?
ANS: 19
```

PARTITION WALLS BETWEEN HOT AND COOL?
ANS: 0

NUMBER OF FLOOR TYPES BETWEEN CONDITIONED AND
UNCONDITIONED AREAS?
ANS: 1

FLOOR TYPE # 1
WHAT IS THE SQUARE FOOT AREA?
ANS: 1540

TYPE THE APPROPRIATE FACTOR:

-SLAB ON GRADE = .1
-FLOOR ABOVE OPEN CRAWLSPACE = 1
-FLOOR ABOVE CLOSED CRAWLSPACE OR BASEMENT = 0
-FLOOR ABOVE NON-AIR CONDITIONED ROOM = .9

FACTOR: ANS: 1
WHAT IS ITS R-VALUE (MIN. = 3)?
ANS: 3
TOTAL FLOOR AREA OF CONDITIONED SPACES?
ANS. 1540

HOW AIRTIGHT IS THE HOME?
(10 = VERY TIGHT, 0 = VERY LEAKY)
ANS: 8

TOTAL AREA OF ALL WINDOWS?
ANS: 230

TYPE THE APPROPRIATE FACTORS:

-SINGLE GLAZED WINDOWS = 1,1
-DOUBLE GLAZED WINDOWS = .5,.8
-TRIPLE GLAZED WINDOWS = .33,.65

FACTOR #1: ANS: .5
FACTOR #2: ANS: .8

WINDOWS THAT FACE DUE NORTH:
WHAT IS THE SQUARE FOOT AREA?
ANS: 0
HOW MUCH SUN DO THEY GET?
(10 = UNSHADED, 0 = FULLY SHADED)
ANS: 10

WINDOWS THAT FACE EAST, SOUTH, OR SOUTHEAST:
WHAT IS THE SQUARE FOOT AREA?
ANS: 115
HOW MUCH SUN DO THEY GET?
(10 = UNSHADED, 0 = FULLY SHADED)
ANS: 10

```
WINDOWS THAT FACE WEST, SOUTHWEST, OR NORTHWEST:
WHAT IS THE SQUARE FOOT AREA?
ANS: 115
HOW MUCH SUN DO THEY GET?
(10 = UNSHADED, 0 = FULLY SHADED)
ANS: 10

WINDOWS THAT FACE NORTHEAST:
WHAT IS THE SQUARE FOOT AREA?
ANS: 0
HOW MUCH SUN DO THEY GET?
(10 = UNSHADED, 0 = FULLY SHADED)
ANS: 10

TOTAL WATTAGE OF ALL ELECTRICAL DEVICES (MIN. = 600)
ANS: 1000

NUMBER OF RESIDENTS (MIN. = 2)?
ANS: 2.5

THERMAL MASS IN THE HOME?
(10 = A LOT, 1 = VERY LITTLE)
ANS: 5

PEAK COOLING LOAD = 32772.9 BTU/HR

COST OF ELECTRICITY PER KWH?
ANS: .065

EER'S OF TWO AIR CONDITIONERS?
AIR CONDITIONER # 1:
ANS: 8
AIR CONDITIONER # 2:
ANS: 6

ANNUAL OPERATING COST =
#1:  $302.59
#2:  $391.59

WHAT DO THE AIR CONDITIONERS COST?
AIR CONDITIONER # 1:
ANS:  $1500
AIR CONDITIONER # 2:
ANS:  $1200

AIR CONDITIONER # 1 COSTS $89.00 LESS TO OPERATE.

RETURN ON INVESTMENT = 29.67%
```

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